A Dynamic Model of Predation *

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Abstract

We study the feasibility and profitability of predation in a parsimonious infinite-horizon, complete information setting where an incumbent may face an entrant, in which case it needs to decide whether to accommodate or predate it. If the entrant exits, a new entrant is born with positive probability. We show that there always exists a Markov perfect equilibrium, which can be of three types: accommodation, predation with no future entry, and predation with hit-and-run entry. We use the model to study alternative antitrust policies, derive the best rules for these policies, and compare their welfare effects.

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1 Introduction

Predatory behavior arises when a firm adopts an aggressive strategy, such as charging low prices, expanding output, launching an extensive advertising campaign, or introducing fighting brands, in order to induce a rival to exit the market.[1] The allegation that a firm has intentionally engaged in predatory behavior is highly controversial. Chicago school scholars such as Bork (1978, p. 154) claim that predatory behavior is "a phenomenon that probably does not exist."[2] The U.S. Supreme Court summarized these views in *Matsushita vs. Zenith* as a "consensus among commentators that predatory pricing schemes are rarely tried, and even more rarely successful."[3] Other scholars however, including Bolton, Brodley, and Riordan (2000) and Edlin (2012), find instead evidence of predatory behavior in a variety of industries.

One reason for Bork's claim that predation "probably does not exist" is that, following the prey's exit, the predator will quickly face a new entrant and will therefore be unable to recoup the losses incurred during the predatory episode. But as Edlin (2012) points out, entry cannot be presumed, and moreover, the role of expectations is not accounted for. Indeed, if a potential entrant expects the incumbent to be aggressive once it enters, it may prefer to stay out of the market; conversely, the incumbent's reaction to entry depends on its expectations about future entrants' behavior.

Another controversy concerns the welfare effects of predation. Scholars such as Areeda and Hovenkamp (2002) and Posner (2001) argue that predatory behavior potentially harms consumers by reducing competition once the prey exits. Other scholars, however, point out that the benefit to consumers during the predatory phase is a sure thing, whereas the resulting harm is speculative, as the prey may not exit and, even if it does, the threat of new entry may induce the incumbent to maintain its aggressive strategy.[4] The welfare effects of predation are thus *a priori* ambiguous.[5]

[1] For instance, in the early 1970's, Maxwell House reacted to Folger's entry into several cities in the East coast of the U.S. with low prices, extensive promotions and advertising, and a fighting brand of regular coffee. After more than five years of litigation, the FTC eventually dismissed the case – see Hilke and Nelson (1989). More recently, the European Commission decided that Qualcomm abused of its dominant position by offering targeted below-cost prices to eliminate Icera, its main competitor at the time in the leading edge segment of the UMTS chipset – see Case AT.39711 – Qualcomm (predation), 2019/C 375/07.

[2] Easterbrook (1981) raises similar doubts and writes "there is no sufficient reason for antitrust law or the courts to take predation seriously."

[3] *Matsushita Elec. Indus. Co. v. Zenith Radio Corp.*, 475 U.S. 574, 589 (1986).

[4] This view is summarized by Judge Breyer, who wrote: "[T]he antitrust laws very rarely reject such beneficial 'birds in hand' for the sake of more speculative (future low-price) 'birds in the bush". See *Barry Wright Corp. v. ITT Grinnell Corp.*, 724 F.2d 227, 234 (1st Cir. 1983).

[5] For instance, Scherer (1976) argues that the overall welfare effect of predation depends on considerations such as the relative costs of the dominant and fringe firms, the minimal scale of

Analyzing the role of incumbents and entrants' expectations, as well as assessing the overall welfare impact of predation, requires a fully dynamic framework. To this end, we consider an infinite horizon game in which an incumbent, I, faces a sequence of potential entrants. We impose only minimal assumptions on the firms' payoffs, which are satisfied by standard IO models. In every period, the game starts in one of two states. In the *monopoly* state, I is initially alone in the market but, with positive probability, a potential entrant E is born and decides whether to enter. In the *competitive* state, I already faces a rival E and decides whether to predate, which reduces E's profit if it stays in the market; having observed I's decision, E decides whether to stay. In both states, E's decision affects I's profit (which is lower if E is active) and determines the state of the next period.

We first characterize the Markov Perfect equilibria (MPE) of this game and show that three types of equilibria can emerge: (i) an *accommodation* equilibrium, in which there is no predation and the first newborn E enters and stays forever; (ii) a *predation* equilibrium with "hit-and-run" entry on the equilibrium path: a newborn E enters, but exits next period when I predates; and (iii) a *monopolization* equilibrium in which a newborn E stays out because it expects predation if it enters. Which type of equilibrium emerges depends on three considerations. First, exclusion may not be feasible; indeed, I's predatory behavior may fail to induce an existing E to exit or a newborn E to stay out. Second, even if exclusion is feasible, I may find it too costly. As anticipated by Edlin (2012), this depends crucially on firms' expectations about their rivals' behavior, which can give rise to multiple equilibria.[6] Indeed, if E expects accommodation in the future, it may not exit when I predates in the current period, which makes predation unprofitable. By contrast, if E expects predation in the future, it exits whenever I predates, which strengthens I's incentive to predate; as a result, a monopolization equilibrium can exist regardless of the probability of future entry. Finally, the form of exclusion (i.e., predation or monopolization) depends on whether hit-and-run entry is profitable.

We then discuss the policy implications of our analysis. The U.S. and EU treatments of predation have been heavily influenced by Areeda and Turner (1975), who argue that below-cost pricing should be deemed predatory. Indeed, in *Matsushita vs. Zenith*, the U.S. Supreme Court defined predatory pricing as "either (i) pricing below the level necessary to sell their products, or (ii) pricing below some appropriate measure of cost."[7] In *Brooke Group*, however, the Court added a recoupment

entry, the incumbent's behavior in case of exit, and whether fringe firms are driven out entirely.

[6] In particular, Edlin writes "Whether predation is a successful strategy depends very much on whether predator and prey believe it is a successful strategy." Our analysis confirms Edlin's intuition and identifies conditions under which multiple equilibria indeed arise.

[7] See *Matsushita* at 585, n. 8. The Court recalled this definition in *Cargill*, where it refers explicitly Areeda and Turner; see *Cargill, Inc. v. Monfort of Colorado, Inc.*, 479 U.S. 104, 117 (1986).

requirement and held that a plaintiff must also prove that "the competitor had a reasonable prospect of recouping its investment in below-cost prices."[8] In the EU, the Court of Justice held in *AKZO* that "Prices below average variable costs [...] by means of which a dominant undertaking seeks to eliminate a competitor must be regarded as abusive," and that "prices below average total costs [...], but above average variable costs, must be regarded as abusive if they are determined as part of a plan for eliminating a competitor."[9]

Our analysis does not support the emphasis on price-cost comparisons, as below-cost pricing is neither necessary nor sufficient for successful predation. If entry costs are high, above-cost prices may suffice to deter entry; conversely, a short-run loss may not drive E out of the market it if expects large enough profits in the long-run. By contrast, the "prospect for recoupment" plays a crucial role in our analysis, which shows how it depends on the likelihood of exit and of future entry.

Our analysis does not support either a complete ban on predation, even if such a ban were enforceable. The reason is that the benefit of low prices during the predatory episode may outweigh the harm from monopoly incurred between exit and new entry, suggesting that legal rules intended to identify and mitigate predation should take into account dynamic considerations. This leads us to consider two rules that do so and are meant to be easier to enforce. The first rule was suggested by Williamson (1977) and Edlin (2002), and is intended to curb the incumbent's response to entry. The second rule was suggested by Baumol (1979), and is instead intended to curb the incumbent's response to exit. We show that both rules can dominate a complete ban on predation by deterring predatory behavior when it is socially harmful, while allowing it when it is socially desirable. We also characterize the optimal policy between laissez-faire, a ban on predation, and these two legal rules.

In the rest of the paper, we proceed as follows. Next, we relate our analysis to the literature on predatory behavior. We then present our model in Section 2 and characterize the equilibrium in Section 3. We discuss antitrust intervention in Section 4 and provide concluding remarks in Section 5. In Appendix A we illustrate the assumed payoff structure within a standard Stackelberg duopoly. All proofs are

[8] See *Brooke Group Ltd. v. Brown & Williamson Tobacco Corp.*, 509 U.S. 209, 225–26 (1993). Although the *Brooke Group* test has proven difficult to meet, numerous predatory pricing cases have survived summary judgment in U.S. courts, while others have survived dismissal, which suggests that predation cases may be successfully litigated in the U.S. - See Hemphill and Weiser (2018).

[9] Case C-62-86, *AZKO Chemie BV v Commission* [1991], ECR I-3359, at paragraphs 71-72 . At paragraph 44 of *Tetra-Pak II*, the Court further clarified that proof of recoupment was not needed (Case C-333/94 P, *Tetra Pak International SA v Commission* [1996], ECR I-5951). In the *Qualcomm* case mentioned above, the EC based its decision on the claim that Qualcomm offered targeted prices "below long-run average incremental costs, and, in any case, below average total costs," and did so "with the intention of eliminating Icera."

in Appendix B.

Related Literature

There is an extensive theoretical literature on predatory behavior. In an early survey, Ordover and Saloner (1989) distinguish three strands in that literature.[10] The first is the "deep pocket" or "long purse" theory, in which the predator seeks to deplete the resources of a financially constrained rival (see, e.g., Telser, 1966, and Bolton and Scharfstein, 1990). The second strand is "predation for reputation," in which the predator wishes to appear tough in order to deter future entrants (see, e.g., Kreps and Wilson, 1982, and Milgrom and Roberts, 1982). The third strand is based on signaling; there the predator's goal is to convince the entrant that staying in the market would be unprofitable, in order to induce it to exit (see, e.g., Roberts, 1986, and Fudenberg and Tirole, 1986) or acquire it at a low price (see, e.g., Saloner, 1987).

This early literature relies directly or indirectly on information problems: the deep pocket theory hinges on capital market imperfections that are typically based on some form of asymmetric information, and in the reputation and signalling theories, the prey is uninformed about market conditions. More recently, Fumagalli and Motta (2013) propose an alternative theory that relies on scale or scope economies: by supplying early buyers at a loss, an incumbent prevents a (possibly more efficient) rival from reaching a viable scale, which in turn enables the incumbent to exploit the remaining buyers.[11] As in much of the earlier literature, they focus on the interaction between an incumbent and a single entrant in a finite-horizon setting.

By contrast, we consider an infinite-horizon, complete information setting where the incumbent may face new potential entrants if the current rival exits. Our analysis highlights the role of firms' expectations: as the horizon is infinite, firms constantly face *strategic uncertainty* about each other's future behavior. We show that this strategic uncertainty suffices to make predation both feasible and profitable, even in the absence of asymmetric information or scale economies. Our approach is in line with Asker and Bar-Isaac (2014), who employ an infinite period, perfect information Markovian framework to study exclusion within a vertical context; in essence, we employ a similar framework to study instead exclusion within a horizontal context.

Our paper is closer to another strand of the predation literature, which also uses infinite-horizon, complete information settings but focuses instead on learning curve dynamics. Cabral and Riordan (1994) study a setting in which, in each period,

[10] For a more recent survey see, e.g., Kobayashi (2010).

[11] A similar insight obtains when multiple buyers face some form of mis-coordination.

two firms compete for a buyer. Winning the current competition lowers future costs due to a learning curve effect; this induces the firm to price aggressively, in order to lower its own future costs and prevent the rival from doing so. When a firm gains a sufficiently large cost advantage over the rival, the latter exits, which further encourages investments in cost-reduction. Their model, as ours, can give rise to multiple equilibria with and without predatory-like behavior, and below-cost pricing is neither a necessary nor sufficient indication of predatory behavior. They also find that predation has ambiguous welfare effects; in particular, by fostering learning and reducing costs, it may benefit consumers even in the long run.[12] An important difference is that they do not allow for new entry, which plays a key role in our setting.

Besanko, Doraszelski, and Kryukov (2014) build on Cabral and Riordan (1994), using numerical simulations that allow for re-entry. They show that exclusionary motives constitute an important driver of competition and compare the equilibrium outcomes with that of a social planner. They find that, due to the learning curve, dynamic price competition generates low deadweight loss. Besanko, Doraszelski, and Kryukov (2020) adapt the definitions of predation from Ordover and Willig (1981) and Cabral and Riordan (1997) to a Markov-perfect industry-dynamics framework and construct sacrifice tests. These tests disentangle an illegitimate profit sacrifice stemming from predatory pricing from a legitimate effort to increase cost efficiency through aggressive pricing.

We focus instead on the debate about the plausibility of predation under persistent threat of entry and its implications for antitrust enforcement. We thus abstract from learning curve effects and show that strategic uncertainty suffices to give rise to predation. Moreover we characterize the conditions under which predation deters entry, and the conditions under which newborn rivals keep entering and the incumbent fights them. Finally, we use our framework to assess the welfare effect of current and alternative legal rules.

2 The model

Consider an infinite-horizon, discrete time setting in which an incumbent I faces a sequence of potential entrants denoted by E. In each period, the game starts in one of two states: (i) a monopoly state, $\mathcal{M}$, in which I is initially the only firm in the market, but E may enter; or (ii) a competitive state, $\mathcal{C}$, in which I and E are both initially in the market, but E may exit. When a newborn E does not enter or an

[12] Cabral and Riordan (1997) considers a two-period Cournot variant in which, conversely, predation may harm consumers in the short-run, as the predator's aggressive behavior may be offset by the prey's softer reaction.

existing E exits, it dies but a new E may be born in future periods. All firms face the same discount factor $\delta \in (0, 1)$.

The timing and profits are as follows:

• In state $\mathcal{M}$, a potential entrant E is born with probability β and decides whether to enter. If E was not born, or was born but decided not to enter, I obtains the monopoly profit π_I^m and the next period starts again in state $\mathcal{M}$. If instead E enters, it incurs a one-time entry cost $k > 0$, I and E obtain the competitive profits π_I^c and $\pi_E^c - k$, and the next period starts in state $\mathcal{C}$.[13]

• In state $\mathcal{C}$, I first decides whether to predate or to accommodate. Having observed I's decision, E decides whether to stay or to exit. If I predates and E exits, I's profit is π_I^p and the next period starts in state $\mathcal{M}$. If E stays despite being predated, the profits of I and E are $\underline{\pi}_I^p$ and π_E^p, and the game remains in state $\mathcal{C}$. If I accommodates and E stays, I and E obtain the same competitive profits as in state $\mathcal{M}$, π_I^c and π_E^c, except that now E does not incur the entry cost, k, and the game remains in state $\mathcal{C}$.[14] If instead E exits, I's profit is $\overline{\pi}_I^c$ and the next period starts in state $\mathcal{M}$.

Table 1 provides a summary of the firms' profits:

State $\mathcal{M}$	E enters	E stays out
	$\pi_I^c, \quad \pi_E^c - k$	$\pi_I^m, \quad 0$

State $\mathcal{C}$	E stays	E exits
I accommodates	$\pi_I^c, \quad \pi_E^c$	$\overline{\pi}_I^c, \quad 0$
I predates	$\underline{\pi}_I^p, \quad \pi_E^p$	$\pi_I^p, \quad 0$

Table 1: Profits

We naturally assume that $\pi_I^m > \pi_I^c > \max\{\pi_I^p, \underline{\pi}_I^p\}$: in state $\mathcal{M}$, I obtains a higher profit when it is alone in the market; and in state $\mathcal{C}$, I obtains a higher profit under accommodation than under predation.[15] Also, to rule out uninteresting cases, we assume that entry is viable under accommodation (E's discounted sum of competitive profits exceeds the entry cost), whereas staying in the market is not viable under predation:

$$\pi_E^c > (1 - \delta)\, k \text{ and } \pi_E^p < 0.$$

[13] An alternative interpretation of the stochastic process is that entry cost is either k with probability β, or is prohibitively costly with probability $1 - \beta$.

[14] The assumption that the profits of I and E are the same as in state $\mathcal{M}$ is not essential and can be relaxed at the cost of additional notational complexity.

[15] While one might assume realistically that I also obtains a higher profit when it operates alone in the market in state $\mathcal{C}$ ($\overline{\pi}_I^c > \pi_I^c$ and $\pi_I^p > \underline{\pi}_I^p$), the analysis does not rely on these assumptions.

These assumptions are sufficiently flexible to allow for product differentiation, price and quantity competition, multi-product firms and (mixed) bundling, and so forth. Importantly, we can either have $\pi_I^p > 0$ or $\pi_I^p < 0$: in case of predation, I's price can be either above or below average cost.[16]

Our setting is very parsimonious. In particular, E must simply decide whether to be in the market or not, and I needs to make a decision only in state $\mathcal{C}$, namely, whether to predate or accommodate E; in state $\mathcal{M}$, I has no decision to make. This pattern can be justified by interpreting the "length" of a period in our model as the time lag before I can react to a change in its environment. Consider for instance a continuous time version, in which I can only choose to either behave "normally" or to "fight", and cannot switch instantaneously.[17] That is, if either entry or exit occurs at time t, I cannot adjust its behavior until time $t + \tau$. Assuming that "fighting" is sufficiently costly, I will behave normally until entry occurs, and will then either stick to this behavior, or fight E as soon as possible, that is, after a time lag τ. Assuming that E, as a new entrant, is more agile and can react at once, E will exit as soon as predation occurs, and I will be able to revert to its pre-entry strategy after the time lag τ.

3 Equilibrium analysis

We focus on pure-strategy Markov Perfect equilibria. A Markov strategy for I is the decision to either predate or accommodate in state $\mathcal{C}$. A Markov strategy for E is the decision to either enter or stay out in state $\mathcal{M}$ if it is born, and a mapping from I's action into the decision to either stay in the market or exit in state $\mathcal{C}$. A Markov Perfect Equilibrium (MPE) is a subgame-perfect equilibrium in which the equilibrium strategies (on and off the equilibrium path) are Markovian.

Three possible types of equilibria may emerge. If I accommodates whenever in state $\mathcal{C}$, the viability assumption $\pi_E^c > (1 - \delta) k$ ensures that (i) in state $\mathcal{C}$, E stays forever, as its per-period profit, π_E^c, is positive, and (ii) in state M, the first newborn E enters the market, as the per-period profit covers the amortization of the entry cost. If instead I predates whenever in state $\mathcal{C}$, the non-viability assumption $\pi_E^p < 0$ ensures that E exits at once when indeed in state $\mathcal{C}$. In state $\mathcal{M}$, a newborn E then enters for one period if its one-period profit, π_E^c, covers the entry cost k, and otherwise stays out of the market.

[16] The classic Stackelberg example presented in Appendix A illustrates the above assumptions as well as the ambiguity of price-cost comparisons.

[17] The implicit assumption that I sustains "unaggressive" behavior after entry – as is indeed the case in the Stackelberg example provided in Appendix – is in line with the previous assumption that competitive profits are the same in states $\mathcal{M}$ and $\mathcal{C}$. Allowing for different forms of "unaggressive" behavior before and after entry would be straightforward.

Our first proposition shows that an equilibrium always exists, and that its type depends mainly on two parameters: E's profit under accommodation, π_E^c, and I's "cost-benefit ratio" of exclusion, λ, reflecting the balance between the profit sacrifice incurred in predation periods, $\pi_I^c - \pi_I^p$, and the monopolization benefit obtained in subsequent periods, $\pi_I^m - \pi_I^c$:

$$\lambda \equiv \frac{\pi_I^c - \pi_I^p}{\pi_I^m - \pi_I^c}.$$

Specifically, let

$$\hat{\pi}_E^c \equiv -\frac{1-\delta}{\delta}\pi_E^p (> 0)$$

and

$$\underline{\lambda} \equiv \frac{(1-\beta)\,\delta}{1-(1-\beta)\,\delta}\,(> 0) \text{ and } \overline{\lambda} \equiv \frac{\delta}{1-\delta}\,(> \underline{\lambda})$$

We have:

Proposition 1 (equilibrium outcomes) *The (pure-strategy) Markov perfect equilibrium outcomes are as follows:*

(i) ***Accommodation:*** *I accommodates entry, and the first newborn E enters and stays forever; such an equilibrium exists if and only if either $\pi_E^c \geq \hat{\pi}_E^c$ or $\lambda \geq \underline{\lambda}$.*

(ii) ***Predation:*** *I predates in case of entry, and newborn E's enter for only one period; such an equilibrium, which features hit-and-run entry, exists if and only if $\pi_E^c \geq k$ and $\lambda \leq \underline{\lambda}$.*

(iii) ***Monopolization:*** *I predates in case of entry, and newborn E's stay out; such an equilibrium exists if and only if $\pi_E^c \leq k$ and $\lambda \leq \overline{\lambda}$.*

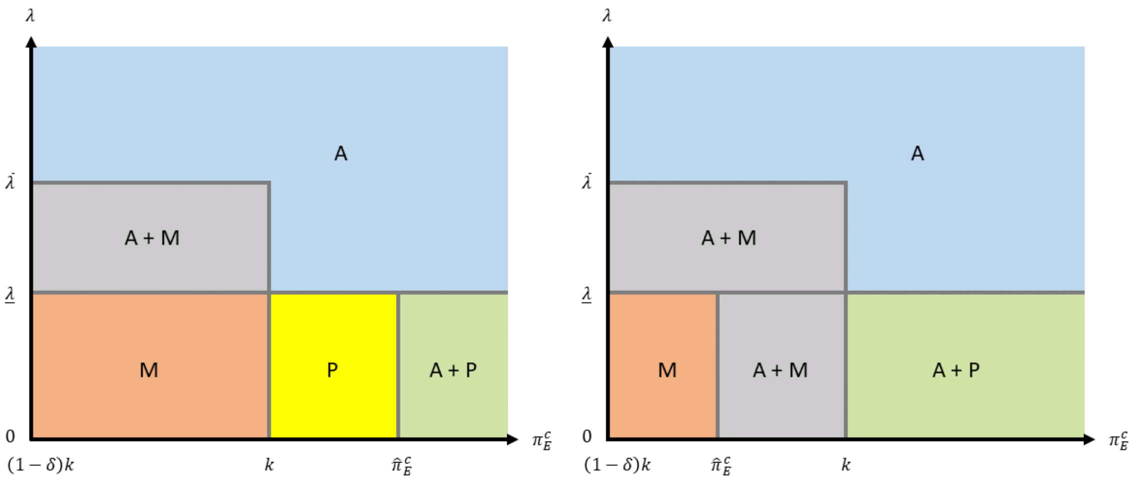
Proof. See Appendix B.1. ■

When E expects accommodation in the future, it anticipates a profit of π_E^c from the next period onward. If this profit is large enough, namely $\pi_E^c \geq \hat{\pi}_E^c$, E is willing to stay in the market even if I were to predate it in the current period.[18] Accommodation is then self-sustainable, as predation does not induce E to exit. If instead $\pi_E^c < \hat{\pi}_E^c$, deviating to predation would trigger exit, but is unprofitable if the cost-benefit ratio is too low, namely $\lambda \geq \underline{\lambda}$: as predation yields a monopolization benefit as long as no other entrant appears, the total expected discounted value of this benefit obtained from next period on is $\underline{\lambda}\,(\pi_I^m - \pi_I^c)$, which is then lower than the short-run sacrifice, $\pi_I^c - \pi_I^p$.

[18] To see why, note that $\pi_E^c \geq \hat{\pi}_E^c$ is equivalent to $\delta\frac{\pi_E^c}{1-\delta} \geq -\pi_E^p$, implying that the future gain from accommodation exceeds the current loss from predation.

When E expects predation in the future, it exits as soon as possible to avoid losses. However, if $\pi_E^c \geq k$, a one-period profit covers the entry cost; the equilibrium thus features hit-and-run entry, followed by predation and exit. For such an equilibrium to exist, I must be willing to predate, which amounts to $\lambda \leq \underline{\lambda}$, as the total expected discounted value of the monopolization benefit (between periods of hit-and-run entry) is again equal to $\underline{\lambda}\,(\pi_I^m - \pi_I^c)$.

Finally, when E expects predation but $\pi_E^c \leq k$, hit-and-run entry is unprofitable; predation is therefore more attractive for I, as it generates a monopolization benefit forever. As a result, the monopolization equilibrium arises for a larger range of the cost-benefit ratio, namely, $\lambda \leq \overline{\lambda}$.



(a) $\hat{\pi}_E^c > k$ (b) $\hat{\pi}_E^c < k$

Figure 1: Equilibrium outcomes

In Figure 1 we display the various outcomes ("A" for accommodation, "P" for predation, and "M" for monopolization), as a function of E's profit π_E^c – in the relevant range $\pi_E^c > (1-\delta)k$ – and of I's cost-benefit ratio of exclusion λ. Accommodation is an equilibrium whenever exclusion is relatively costly for I ($\lambda \geq \underline{\lambda}$) and/or entry is sufficiently profitable for E ($\pi_E^c \geq \hat{\pi}_E^c$). Predation is instead an equilibrium when it is relatively beneficial for I ($\lambda \leq \underline{\lambda}$) and hit-and-run entry is profitable for E ($\pi_E^c \geq k$). Finally, monopolization is an equilibrium if exclusion is relatively beneficial for I ($\lambda \leq \overline{\lambda}$) and hit-and-run entry is unprofitable for E ($\pi_E^c \leq k$).

As mentioned in the Introduction, Bork and Easterbrook have expressed skepticism about predation, based on the argument that, once the prey exits, new entry would render predation unprofitable. Proposition 1 offers a more nuanced view. It does confirm the intuition that exclusion is less likely when entry is easy. In our model, this is the case when the likelihood that a new entrant is born, β, is high (i.e., close to 1) and the entry cost, k, is low. In terms of Figure 1, the horizontal line $\lambda = \underline{\lambda}$ shifts downward as β increases and the vertical line $\pi_E^c = k$ shifts inward as k decreases; as a result, accommodation arises for a wider set of parameters, and constitutes the unique equilibrium in the limit case where $\beta = 1$ (implying $\underline{\lambda} = 0$) and $k = 0$. However, outside this limit case, exclusion arises whenever it is not too costly (namely, when the cost-benefit ratio λ is sufficiently low): predation equilibria then exist whenever $\beta < 1$ (even if $k = 0$), and monopolization equilibria exist whenever $\pi_E^c \leq k$ (even if $\beta = 1$). This suggests that, although Bork's and Easterbrook's skepticism is justified in the limit, predatory behavior remains a valid concern in general.

Moreover, as anticipated by Edlin (2012), Proposition 1 shows that the role of firms' expectations about their rival's behavior can lead to a multiplicity of equilibria, in which accommodation may coexist with temporary or permanent exclusion. This occurs in two instances.[19] If $\lambda < \underline{\lambda}$, even temporary exclusion is profitable for I. In this case, exclusion (temporary if $\pi_E^c \geq k$, and permanent otherwise) can always arise, because if E expects predation in the future, then it exits whenever I predates, which in turn induces I to do so. Yet accommodation can also arise when $\pi_E^c \geq \hat{\pi}_E^c$, because if E expects accommodation in the future, then it would stay in the market even if I were to deviate to predation.

If instead $\lambda \in \left[\underline{\lambda}, \overline{\lambda}\right]$, exclusion is profitable for I only when it is permanent, that is, when hit-and-run entry is not profitable: $\pi_E^c \leq k$. In this case, monopolization can indeed arise, because if I expects future E's to exit in case of predation, it has an incentive to do so whenever a new E enters, which in turn deters entry. Yet accommodation can also arise, because if I anticipates entry in the future, then it does not find it profitable to predate, as the benefit of a temporary monopoly position does not compensate the short-run sacrifice. It is worth noting that, in the range where $\pi_E^c \leq k$ and $\lambda \leq \overline{\lambda}$, the monopolization equilibrium exists *regardless* of the probability β that a potential entrant arrives: I is willing to predate even when $\beta \to 1$, as potential entrants, anticipating predation, prefer to stay out.

We conclude this section by noting that the incumbent always prefers the exclusionary equilibria:

Proposition 2 (profitable exclusion) *I prefers the predation or monopolization equilibria whenever they coexist with the accommodation equilibrium.*

Proof. See Appendix B.2. ■

[19] Another (non-generic) instance arises when $\pi_E^c = k$, implying that E is indifferent between staying or exiting when it expects predation in the future. The monopolization and predation equilibria then coexist if $\lambda \leq \underline{\lambda}$. For the sake of exposition, we will assume that when indifferent, E enters, implying that the predation equilibrium is then selected.

The intuition is straightforward and relies on the observation that, in any exclusionary equilibrium, I could always secure the accommodation payoff by never predating. Hence, by revealed preferences, exclusion must be more profitable for I whenever it arises in equilibrium.

4 Policy implications

As mentioned in the Introduction, designing an appropriate policy for dealing with predation involves two main difficulties. The first difficulty is that the welfare effects of predatory behavior are in general ambiguous, because intense competition during the predatory phase may be pro-competitive and outweigh the anticompetitive effect when the prey exits. Hence, whether antitrust laws should prohibit predation is unclear. We address this issue in Subsection 4.1.

Another difficulty is that in many, or even most, real-life cases it is unclear whether a given strategy is legitimate and reflects healthy competition, or is predatory and intended to induce a rival to exit. Recognizing this difficulty, several legal rules have been proposed to identify predatory behavior.[20] The most well-known legal rule is the Areeda and Turner (1975) rule, which deems prices below average variable cost as predatory. Although the U.S. and EU antitrust approaches to predatory pricing build on it, this rule has been criticized on several grounds.

First, a static price-cost comparison may lead to substantial type I and type II errors. Type I errors (wrongly condemning the innocent) may arise because prices below cost may be desirable regardless of the impact on rivals, for instance, to move down the learning curve, to signal high quality to consumers via an introductory offer, or to attract consumers and sell them other products. Conversely, type II errors (failing to convict the guilty) can arise because a price above average variable cost may suffice to induce a weaker rival to exit.[21] Second, even if at first glance the Areeda-Turner rule may appear simple to enforce, in reality average variable costs are often difficult to measure, especially when firms have large common costs. Third, the rule is static and overlooks the dynamic nature of predatory pricing. This has led scholars to propose rules that avoid the difficulty of measuring the alleged predator's cost and examine instead its reaction to entry or exit, which is arguably easier to observe and measure. We study two such rules in Subsections 4.2 and 4.3.

[20] For an early overview and assessment of these rules, see, e.g., Joskow and Klevorick (1979).

[21] For instance, according to Edlin (2002), in the late 1990s American Airlines succeeded in driving Vanguard Airlines out of the Kansas City-Dallas Fort Worth route by lowering its fares by over twenty-five percent and increasing the frequency of its flights. The DOJ sued American Airlines for predatory pricing but lost because American Airlines' fares were found to be above cost.

For the purpose of the analysis, we assume that regulators (e.g., competition agencies) rely on a given welfare criterion, and denote by w^m, w^c, and w^p the per-period welfare under monopoly, competition, and predation.[22] It is natural to assume that $w^m < w^c$ (competition increases welfare) and $w^m < w^p$ (aggressive predatory behavior increases welfare in the short-term). The comparison between w^c and w^p is a priori less clear, as in the latter case I is alone in the market but behaves aggressively. Finally, we assume that in case of entry, welfare is $w^c - \alpha k$, where $\alpha \in [0,1]$ denotes the share of the entry cost that regulators take into account.[23]

To assess the equilibrium level of welfare, we will assume that states $\mathcal{M}$ and $\mathcal{C}$ prevail according to their *long-run* probabilities of occurrence, which we denote by $\mu_{\mathcal{C}}$ and $\mu_{\mathcal{M}}$. In an accommodation equilibrium, state $\mathcal{C}$ eventually prevails with probability 1, so total discounted welfare is

$$W^A = \frac{w^c}{1-\delta}.$$

In a monopolization equilibrium, state $\mathcal{M}$ eventually prevails with probability 1, so total discounted welfare is

$$W^M = \frac{w^m}{1-\delta}.$$

Finally, in a predation equilibrium, expected welfare is $(1-\beta)\, w^m + \beta\,(w^c - \alpha k)$ in state $\mathcal{M}$ and w^p in state $\mathcal{C}$. As state $\mathcal{C}$ occurs if and only if a new E was born in the previous period, the long-run probabilities of states $\mathcal{M}$ and $\mathcal{C}$ satisfy

$$\mu_{\mathcal{C}} = \beta \mu_{\mathcal{M}},$$

which, using $\mu_{\mathcal{C}} + \mu_{\mathcal{M}} = 1$, yields:

$$\mu_{\mathcal{M}} = \frac{1}{1+\beta} \text{ and } \mu_{\mathcal{C}} = \frac{\beta}{1+\beta}.$$

Total expected discounted welfare in a predation equilibrium in the long run is thus given by:

$$W^P \equiv \frac{\mu_{\mathcal{M}}\left[(1-\beta)\, w^m + \beta\,(w^c - \alpha k)\right] + \mu_{\mathcal{C}} w^p}{1-\delta} = \frac{(1-\beta)\, w^m + \beta\,(w^c + w^p - \alpha k)}{(1+\beta)\,(1-\delta)}. \tag{1}$$

[22]Many jurisdictions, including the U.S., the UK, and the EU, focus on consumer surplus (OECD, 2012, p. 27). Other countries, including Canada and Norway, pursue instead a total welfare standard that assigns an equal weight to consumer surplus and profits (OECD, 2012, p. 27), whereas Australia places a larger weight on consumer surplus than on profits (OECD, 2012, p. 66-67).

[23]For example, $\alpha = 0$ when regulators focus on consumer surplus, and $\alpha = 1$ when they focus instead on total welfare.

We further assume that hit-and-run entry is socially desirable:

$$w^m < \frac{w^c + w^p - \alpha k}{2}.$$

This assumption ensures that welfare is lowest in the monopolization equilibrium (i.e., $W^M < \min\{W^A, W^P\}$). It is particularly likely to hold when a predation equilibrium exists, because then $k < \pi_E^c$.[24] The welfare comparison between the predation and accommodation equilibria is *a priori* ambiguous, as it depends on the welfare impact of I's aggressive behavior in case of predation.

4.1 Banning Predation

To assess the effect of a complete ban on predation, we compare the equilibrium welfare levels with those in a counterfactual where predation is no longer possible in state $\mathcal{C}$.[25] It follows that, on the equilibrium path, a newborn E eventually enters the market in state $\mathcal{M}$ and stays forever; total discounted welfare is therefore W^A. In the following proposition we characterize the conditions under which such a ban improves welfare:

Proposition 3 (banning predation) *The welfare implications of a ban on predation are as follows:*

(i) If accommodation prevails under laissez-faire, then a ban is irrelevant.

(ii) If predation prevails under laissez-faire, then a ban strictly enhances welfare (i.e., $W^A > W^P$) if and only if

$$w^c > (1 - \beta)\, w^m + \beta\, (w^p - \alpha k)\,.$$

(iii) If monopolization prevails under laissez-faire, then a ban strictly enhances welfare.

Proof. See Appendix B.3. ■

A ban on predation has an effect only if an exclusionary equilibrium arises under laissez-faire. In case of a monopolization equilibrium, E never enters and I becomes a permanent monopolist. A ban on predation is then clearly socially desirable, as in each period it increases welfare from the monopoly to the competitive level.

[24] This is indeed the case in the Stackelberg example presented in Appendix A.

[25] This counterfactual is largely theoretical because, as discussed above, it is often hard in practice to determine whether a firm's strategy is legitimate or predatory.

In case of a predation equilibrium, "hit-and-run" phases (one period of entry, followed by one period of predation and exit) alternate with monopoly phases. Compared with accommodation, in hit-and-run phases a social entry cost αk is incurred in the first period, and welfare changes from w^c to w^p in the second period; in monopoly periods, welfare decreases from w^c to w^m. It follows that accommodation is strictly preferable so long as welfare under "normal competition", w^c, exceeds a weighted average of welfare in monopolization periods, w^m, and in predatory periods, $w^p - \alpha k$, with weights reflecting the relative frequency of these periods.

Proposition 3 is consistent with Cabral and Riordan (1997), who also show that a ban on predation may not be desirable. An important difference is that in their model, the incumbent's output expansion during the predatory phase lowers its cost due to a learning curve effect. As a result, consumers may benefit from predation even when the prey exits. By contrast, in our model consumers benefit from predation only during the predatory phase.

4.2 Curbing the Response to Entry

In this section we consider a legal rule proposed by Williamson (1977) and Edlin (2002) to identify and mitigate predatory behavior. Unlike that of Areeda and Turner, this rule is not cost based; rather it is intended to curb incumbents' ability to react to entry for some time. Specifically, Williamson (1977) proposed an "output restriction rule" stipulating that "the dominant firm cannot increase output above the pre-entry level" for a period of $12-18$ months. Edlin (2002) proposed a closely related rule requiring that "if an entrant prices twenty percent below an incumbent monopoly, the incumbent's prices will be frozen for twelve to eighteen months," but added that "[T]he exact operationalization of the rule (twenty percent threshold and twelve to eighteen months duration) could vary by industry or be decided on a case-by-case basis." Although Edlin's proposal differs from that of Williamson in terms of its specifics, in our parsimonious model the two are isomorphic.

To explore the implications of these proposals, we consider a *Williamson-Edlin rule* defined as follows: in the event of entry, I's strategy in state $\mathcal{M}$ is "frozen" for T periods. I and E thus obtain π_I^c and $\pi_E^c - \alpha k$ in the period of entry, and π_I^c and π_E^c in each of the ensuing $T-1$ freeze periods. Once the freeze is over, the state switches to $\mathcal{C}$, and I is free to predate if it chooses to do so. This rule protects the entrant from predation for T periods. As T increases, it progressively extends the entrant's protection from laissez-faire (for $T=1$) to a complete ban on predation (for $T \to \infty$).

Introducing such a rule may influence the equilibrium in three ways. First, it may affect the path of a given type of equilibrium, e.g., by leading to a modified predation equilibrium where the duration of hit-and-run phases is extended to T periods. Second, it may affect the type of equilibrium that may arise. Third, when multiple types of equilibria exist with and without it, the rule could in principle also serve as a coordination device and induce a switch from one type of equilibrium (under laissez-faire) to another (when the rule is in place). However, as many other coordination devices are available (e.g., sunspots or public announcements), we shall maintain the conservative assumption that the rule does not affect the choice between accommodation and exclusion:

Assumption A: *When multiple equilibria co-exist under the rule, the accommodation equilibrium is selected if and only if it is already selected under laissez-faire.*

Under the Williamson-Edlin rule, a new entrant can secure a minimal discounted profit given by

$$(1+\delta+....+\delta^{T-1})\pi_E^c - k = \frac{\pi_E^c}{\psi(T)} - k,$$

where

$$\psi(T) \equiv \frac{1-\delta}{1-\delta^T} \tag{2}$$

is strictly decreasing in T, from 1 for $T=1$ to $1-\delta$ for $T=\infty$. By expanding the duration of the hit-and-run phases, the Williamson-Edlin rule thus also enhances their profitability. Specifically, when $\pi_E^c \geq k$, entry is viable even without a freeze period. By contrast, if $\pi_E^c < k$, the minimal freeze duration that makes entry viable, T_{WE}^M, exceeds 1 and is uniquely defined by

$$\psi(T_{WE}^M)k = \pi_E^c.$$

Building on these observations leads to:

Proposition 4 (Williamson-Edlin rule) *The Williamson-Edlin rule affects the equilibrium outcome as follows:*

(i) If the accommodation equilibrium prevails under laissez-faire, the rule is irrelevant.

(ii) If instead the predation equilibrium prevails under laissez-faire, the rule modifies it by enabling E to stay in the market during the T periods of the freeze before exiting.

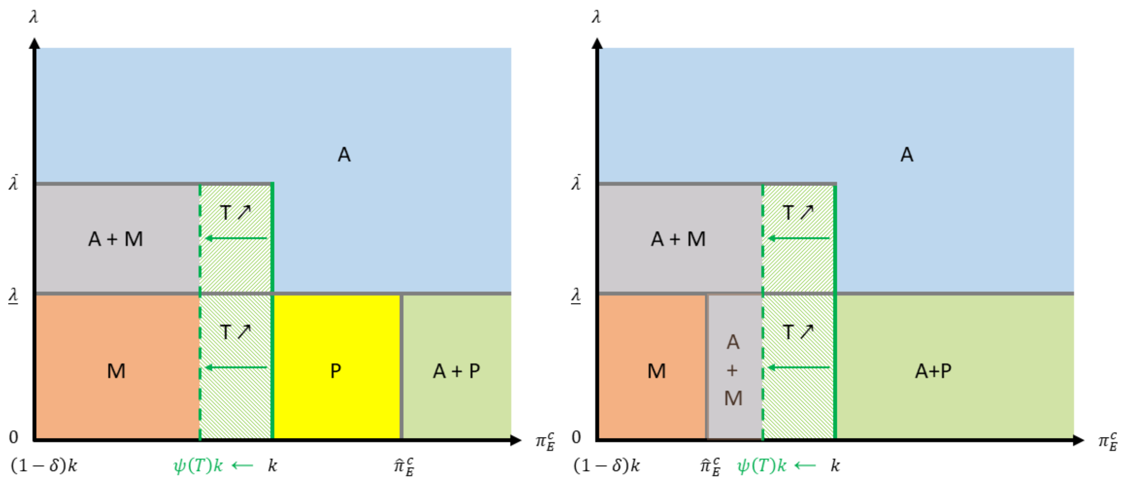
(iii) Finally, if the monopolization equilibrium prevails under laissez-faire, the rule is irrelevant unless $T > T_{WE}^M$, in which case the rule induces a switch to accommodation if $\lambda > \underline{\lambda}$, and to the modified predation equilibrium otherwise.

Proof. See Appendix B.4. ■

Proposition 4 first stresses that the Williamson-Edlin rule does not affect the scope for accommodation. Indeed, the rule has no bite on the equilibrium path and on E's reaction to I's deviation to predation; hence, accommodation remains self-sustainable whenever entry is sufficiently profitable (i.e., when $\pi_E^c \geq \hat{\pi}_E^c$). Furthermore, once the freeze is over, I's ability and incentive to deviate and predate remain unchanged; hence, as before, accommodation can also arise whenever $\lambda \geq \underline{\lambda}$.

Proposition 4 also shows that the rule does not affect I's incentive to predate in any exclusionary equilibrium. For the monopolization equilibrium, this holds by construction: as I expects no future entry regardless of the rule, it is willing to predate whenever $\lambda \leq \overline{\lambda}$, as before. But this is also true for the predation equilibrium, where I remains willing to predate whenever $\lambda \leq \underline{\lambda}$. This is because, in the limit case where predation is barely sustainable, the monopolization benefit is the same as in an accommodation equilibrium, where it is unaffected by the rule.

The Williamson-Edlin rule however increases the duration and profitability of hit-and-run phases, which encourages entry and reduces the scope for monopolization. Specifically, hit-and-run entry becomes viable for a larger range of parameters, namely, whenever $\pi_E^c \geq \psi(T_{WE}^M)k$. A long enough freeze thus induces E to enter even if it expects I to predate at the end of the freeze; the equilibrium then switches from monopolization to predation if exclusion remains profitable (i.e., if $\lambda < \underline{\lambda}$), and to accommodation otherwise. In particular, as $T \to \infty$, the first newborn E enters and competes forever, and the rule thus essentially replicates a ban on predation.



(a) $\hat{\pi}_E^c > k$ (b) $\hat{\pi}_E^c < k$

Figure 2: Impact of the Williamson-Edlin rule

We illustrate these findings in Figure 2. The Williamson-Edlin rule leaves unchanged the horizontal boundaries below which the exclusionary equilibria exist (i.e., $\lambda = \overline{\lambda}$ for monopolization and $\lambda = \underline{\lambda}$ for predation), as well as the vertical boundary beyond which accommodation is self-sustainable (i.e., $\pi_E^c = \hat{\pi}_E^c$). By contrast, the rule shifts inward the vertical boundary beyond which hit-and-run entry is viable, which becomes $\pi_E^c = \psi(T)k$, with $\psi(T)k$ decreasing from k when $T = 1$ to $(1-\delta)\,k$ as $T \to \infty$. Thus the region where monopolization can arise shrinks, and disappears altogether as $T \to \infty$. Thus, if monopolization arises under laissez-faire, it is progressively replaced by accommodation when $\lambda \in (\underline{\lambda}, \overline{\lambda}]$, and by predation when $\lambda \leq \underline{\lambda}$. In both cases welfare is enhanced, as it is lowest under monopolization.

We now study the socially optimal duration of the freeze under the Williamson-Edlin rule. As the freeze does not occur along the accommodation and monopolization equilibrium paths, total discounted welfare remains equal to W^A and W^M. By contrast, the rule increases the frequency of competition periods in a predation equilibrium. Specifically, the equilibrium path switches from monopoly to T periods of competition with probability β, before reverting to monopoly after one period of predation. We show in Appendix B.5 that, as a result, total expected discounted welfare is now given by

$$W_{WE}^P(T) \equiv \frac{(1-\beta)w^m + \beta\,(w^p - \alpha k) + \beta T w^c}{(1+\beta T)\,(1-\delta)},$$

which varies monotonically from W^P to W^A as T increases from 1 to ∞.

We now characterize the socially optimal duration of the freeze under the Williamson-Edlin rule:[26]

Proposition 5 (curbing reaction to entry) *The socially optimal duration of the freeze under the Williamson-Edlin rule is as follows:*

(i) If accommodation prevails under laissez-faire, then the rule is irrelevant.

(ii) If instead predation prevails under laissez-faire, then:

- *a ban ($T = \infty$) is socially optimal if $W^A > W^P$;*
- *laissez faire ($T = 1$) is uniquely socially optimal if $W^A < W^P$.*

(iii) Finally, if monopolization prevails under laissez-faire, then:

- *any duration $T > T_{WE}^M$ is socially optimal if $\lambda > \underline{\lambda}$;*
- *a ban ($T = \infty$) is socially optimal if $\lambda \leq \underline{\lambda}$ and $W^A > W^P$;*

[26] We focus on the generic case where $W^A \neq W^P$. In the boundary case where $W^A = W^P$, any duration is optimal if predation initally prevails, and any duration $T > T_{WE}^M$ is optimal if instead monopolization prevails.

- *a duration T slightly above T^M_{WE} is socially optimal if $\lambda \leq \underline{\lambda}$ and $W^A < W^P$.*

The intuition for Proposition 5 is as follows. If accommodation prevails anyway, the value of T is irrelevant. If instead predation prevails under laissez-faire (i.e., for $T = 1$), extending the duration of the freeze does not disrupt the equilibrium but increases the frequency of competition periods. As a result, welfare progressively varies with T from W^P to W^A. Hence, if $W^A > W^P$, a ban on predation (i.e., $T = \infty$) is optimal, otherwise laissez-faire (i.e., $T = 1$) is optimal.

Finally, if monopolization prevails under laissez-faire, it survives as long as the freeze fails to make hit-and-run entry profitable, i.e., as long as $T \leq T^M_{WE}$. As welfare is lowest under monopoly, it is always desirable to set $T > T^M_{WE}$, to induce a switch from monopolization to either accommodation (if $\lambda > \underline{\lambda}$) or predation (if $\lambda \leq \underline{\lambda}$). When the rule triggers a switch to accommodation, any $T > T^M_{WE}$ is optimal. When instead the rule triggers a switch to predation, $T = \infty$ is optimal if a ban on predation is desirable; otherwise, the shortest T inducing a switch from monopolization to predation is optimal.

4.3 Curbing the Response to Exit

Baumol (1979) proposed a legal rule intended to curb the incumbent's ability to react to exit rather than to entry. The idea is to reduce the scope for recoupment, by forbidding the incumbent to increase its price or restrict its output once the prey exits. Although Baumol advocated a "quasi-permanent" constraint,[27] we allow for more flexibility and consider the following *Baumol rule*: if I predates in state $\mathcal{C}$, it must continue to do so for at least T periods. The case where $T = 1$ corresponds to our baseline setting, and the limit case where $T \to \infty$ coincides with Baumol's original proposal. As we shall see, although this rule does not formally nest a complete ban on predation as a special case, recoupment becomes impossible when $T \to \infty$, and so I thus never predates in equilibrium; hence, the outcome is equivalent to that of a complete ban.

The Baumol rule extends the minimum duration of predation phases, which has two implications. First, this raises E's loss from predation from π^P_E to $\pi^P_E / \phi(T)$, where

$$\phi(T) \equiv \delta^{T-1} \frac{1-\delta}{1-\delta^T} \left(= \delta^{T-1} \psi(T)\right)$$

[27] Baumol explains his proposal as follows: "Under such an arrangement, the established firm would be put on notice that its decision to offer service at a low price is tantamount to a declaration that this price is compensatory, and thus, that it can be expected, in the absence of exogenous changes in costs or demands, to offer the service at this price for the indefinite future."

is strictly decreasing in T, from 1 for $T = 1$ to 0 for $T = \infty$. Second, this also raises the cost of predation for I, and postpones the benefit of monopolization; as a result, the benefit-to-cost ratio λ is also multiplied by $1/\phi(T)$. It follows that, as T increases, predation is more likely to be feasible (i.e., accommodation is less likely to be self-sustainable) but its profitability decreases. Given Assumption A, introducing the Baumol rule may therefore influence the equilibrium in two ways. First, it may lead to a different *modified predation* equilibrium, where the duration of predatory phases is extended to T periods. Second, it may affect the type of equilibrium that arises, by making accommodation no longer self-sustainable and/or by discouraging I from predating.

To characterize further the impact of the Baumol rule on the equilibrium outcomes, it is useful to introduce the thresholds T_B^A, T_B^P and T_B^M, implicitly defined by

$$\phi\left(T_B^A\right)\pi_E^c = \hat{\pi}_E^c, \qquad \phi\left(T_B^P\right)\underline{\lambda} = \lambda, \text{ and } \qquad \phi\left(T_B^M\right)\overline{\lambda} = \lambda.$$

The threshold T_B^A is the maximal duration of the freeze for which accommodation remains self-sustainable. Indeed, if E expects accommodation after T periods, it will stay in the market despite being predated so long as the discounted profits from accommodation, $\delta^T \pi_E^c / (1-\delta)$, exceed its losses during the predatory phase, $\pi_E^P / \psi(T)$, which amounts to $T \leq T_B^A$. Similarly, T_B^P is the maximal duration of the freeze for which predation remains profitable for I when it expects hit-and-run entry in the future, and T_B^M is the maximal duration of the freeze for which predation remains profitable for I when it leads to monopolization. Obviously, $T_B^A \geq 1$ always exists and is unique when $\hat{\pi}_E^c \leq \pi_E^c$; likewise, $T_B^P \geq 1$ always exists and is unique when $\lambda \leq \underline{\lambda}$, and $T_B^M \geq 1$ always exists and is unique when $\lambda \leq \overline{\lambda}$.

We have:

Proposition 6 (Baumol rule) *The Baumol rule affects the equilibrium outcome as follows:*

(i) If the accommodation equilibrium prevails under laissez-faire, the rule is irrelevant unless $\hat{\pi}_E^c \leq \pi_E^c < \hat{\pi}_E^c \underline{\lambda}/\lambda$ *and* $T \in (T_B^A, T_B^P)$*, in which case it induces a switch to the monopolization equilibrium if* $\pi_E^c \leq k$*, and to the modified predation equilibrium if instead* $\pi_E^c \geq k$*.*

(ii) If instead the predation equilibrium prevails under laissez-faire, the rule induces a switch to accommodation if $T > T_B^P$*, otherwise it only modifies the predation equilibrium by forcing* I *to predate for* T *periods in case of entry.*

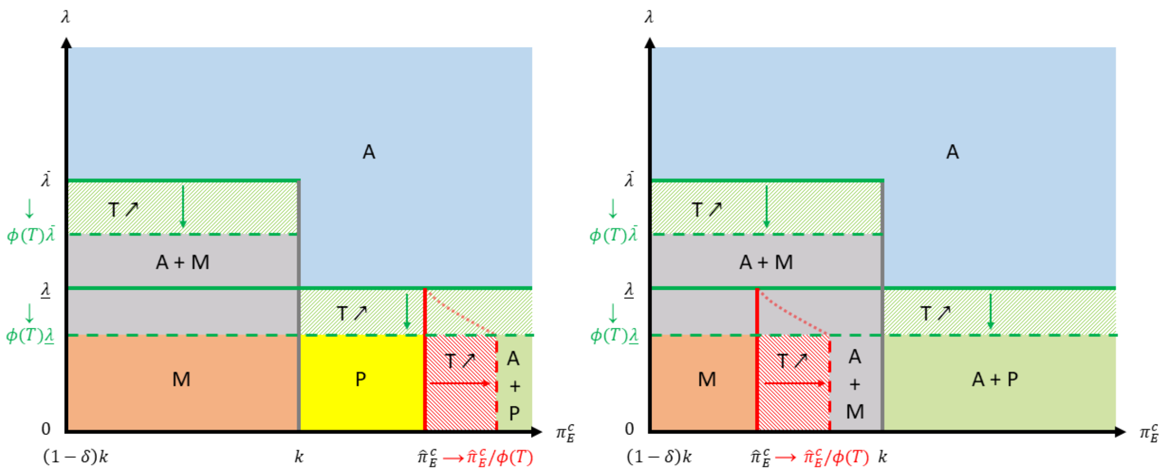
(iii) Finally, if the monopolization equilibrium prevails under laissez-faire, the rule induces a switch to accommodation if $T > T_B^M$*, otherwise it is irrelevant.*

Proof. See Appendix B.6. ■

By extending *de facto* the minimum duration of predation phases, the Baumol rule increases I's cost of predation and postpones the recoupment phase. This, in turn, discourages exclusion and expands the range of parameters for which accommodation is an equilibrium. Specifically, we show in Appendix B.6 that the rule reduces the thresholds $\overline{\lambda}$ and $\underline{\lambda}$ by a factor of $\phi(T)\,(\leq 1)$.

Perhaps more surprisingly, however, by imposing a minimum duration on predatory phases, the rule can also *reduce* the scope for *self-sustainable* accommodation. Indeed, if E stays in the market after a deviation to predation, then, even if it expects accommodation in the future, it now incurs higher losses due to the longer predatory phase. This, in turn, discourages E from entering or staying in the market. As a result, the threshold for self-sustainable accommodation, $\hat{\pi}_E^c$, is inflated by a factor of $1/\phi(T)$.

It is worth noting that, while the Baumol rule affects the scope for exclusion, it does not affect the type of exclusionary equilibria that may arise. This is because the rule has no impact on the profitability of hit-and-run entry in either exclusionary equilibrium, as E expects immediate predation in state $\mathcal{C}$ anyway. This is in contrast to the Williamson-Edlin rule which, by extending the duration of hit-and-run entry phases, expands the range of parameters for which predation prevails over monopolization.



(a) $\hat{\pi}_E^c > k$ (b) $\hat{\pi}_E^c < k$

Figure 3: Impact of the Baumol rule

We illustrate these findings in Figure 3. First, by reducing the profitability of exclusion for I, the Baumol rule expands the region where accommodation is the unique equilibrium. Specifically, the rule shifts down from $\overline{\lambda}$ to $\phi(T)\,\overline{\lambda}$ the horizontal boundary below which monopolization is profitable for I, and it also shifts down from $\underline{\lambda}$ to $\phi(T)\underline{\lambda}$ the horizontal boundary below which predation is profitable for I. As a result, the equilibrium may switch from exclusion (namely, monopolization when $\pi_E^c < k$ and predation otherwise) to accommodation, as depicted by the horizontal dashed lines. In particular, as $T \to \infty$, $\phi(T) \to 0$ and accommodation becomes the unique equilibrium for all values of λ.

Second, by increasing the minimal duration of predatory phases and the associated harm for E, the rule shifts outward from $\hat{\pi}_E^c$ to $\hat{\pi}_E^c/\phi(T)$ the vertical boundary beyond which accommodation is self-sustainable. As a result, it may induce a switch from accommodation to exclusion if $\lambda \leq \underline{\lambda}$. Specifically, for a given $\lambda \leq \underline{\lambda}$ and $\pi_E^c \geq \hat{\pi}_E^c$, the switch occurs when T is large enough to ensure that accommodation is no longer self-sustainable (i.e., $\pi_E^c < \hat{\pi}_E^c/\phi(T)$), but not so large that predation becomes unprofitable (i.e., $\lambda \leq \phi(T)\underline{\lambda}$). Meeting these two requirements is feasible only if

$$\lambda\pi_E^c < \underline{\lambda}\hat{\pi}_E^c, \tag{3}$$

which corresponds to the area lying below the dotted curve. Conversely, whenever $\hat{\pi}_E^c \leq \pi_E^c < \hat{\pi}_E^c\underline{\lambda}/\lambda$, any $T \in \left(T_B^A, T_B^p\right)$ induces a switch from accommodation to exclusion, as depicted by the vertical dashed line.

As the rule has no effect on the accommodation and monopolization equilibrium paths, total discounted welfare still remains equal to W^A and W^M. By contrast, the rule extends the duration of predatory phases along the predation equilibrium path. We show in Appendix B.7 that, as a result, total expected discounted welfare becomes equal to:

$$W_B^P(T) \equiv \frac{(1-\beta)\, w^m + \beta\,(w^c - \alpha k) + \beta T w^p}{(1+\beta T)(1-\delta)}.$$

As competition yields higher per-period welfare than monopoly or entry (i.e., $w^c > \max\{w^m, w^c - \alpha k\}$), if in addition $w^c \geq w^p$, then $W_B^P(\cdot) < W^A$ (as predation then reduces welfare during the predatory period as well as after E exits). If instead $w^p > w^c$, periods of predation yield the highest welfare; $W_B^P(T)$ then increases with T, and exceeds W^A for T large enough.

The next proposition builds on these observations to characterize the socially optimal duration of the freeze under the Baumol rule.[28]

Proposition 7 (curbing reaction to exit) *The socially optimal freeze duration under the Baumol rule is as follows:*

(i) If accommodation prevails under laissez-faire, then the rule has no impact unless $\hat{\pi}_E^c \leq \pi_E^c < \hat{\pi}_E^c\underline{\lambda}/\lambda$, in which case:

[28] We ignore integer issues. Otherwise, T_B^P should be replaced with the largest integer value in the range (T_B^A, T_B^P).

- *a duration slightly below T_B^P is socially optimal if $\pi_E^c \geq k$ and $W_B^P(T_B^P) > W^A$;*

- *laissez-faire (or any other $T \notin (T_B^A, T_B^P)$) is socially optimal otherwise.*

(ii) If instead predation prevails under laissez-faire, then:[29]

- *$T = T_B^P$ is uniquely socially optimal if $W_B^P(T_B^P) > W^A$;*

- *any $T > T_B^P$ is socially optimal otherwise if $W_B^P(T_B^P) < W^A$.*

(iii) Finally, if monopolization prevails under laissez-faire, then any $T > T_B^M$ is socially optimal.

Proof. See Appendix B.7. ■

The intuition for Proposition 7 is simple. When accommodation prevails under laissez-faire, a switch to monopolization is never desirable, whereas a switch to predation may be desirable if welfare is higher under predation than under competition (i.e., $w^p > w^c$). As expected welfare then increases with the duration of the freeze, if such a switch is feasible (namely, if $\max\{k, \hat{\pi}_E^c\} \leq \pi_E^c \leq \hat{\pi}_E^c \underline{\lambda}/\lambda$), it is optimal to choose the longest duration inducing it (i.e., slightly below T_B^P), provided that doing so indeed dominates accommodation (i.e., $W_B^P\left(T_B^P\right) > W^A$). Otherwise, laissez-faire (or any T that does not destabilize accommodation) is socially optimal.

When instead predation prevails under laissez-faire, the Baumol rule either increases the frequency of predation periods (if $T \leq T_B^P$), or induces a switch to accommodation (if $T > T_B^P$). Triggering such a switch is clearly socially optimal if $w^c \geq w^p$, because then accommodation dominates predation: $W^A > W_B^P(\cdot)$. If instead $w^p > w^c$, increasing the duration of freeze is welfare-enhancing as long as predation remains an equilibrium (i.e., $W_B^P(T)$ increases with T for $T \leq T_B^P$), implying that the Baumol rule dominates laissez-faire (i.e., $W_B^P(T) > W^P$). There are then two relevant options: setting $T = T_B^P$ to maximize $W_B^P(T)$, subject to preserving predation, or setting $T > T_B^P$ to ensure a switch from predation to accommodation, in which case total welfare is W^A. The first option dominates whenever a ban on predation is not socially desirable (as we then have $W^A < W^P < W_B^P\left(T_B^P\right)$), and may also dominate if a ban on predation is preferable to laissez-faire (namely, if $W^P < W^A < W_B^P\left(T_B^P\right)$).

Finally, when monopolization prevails under laissez-faire, the Baumol rule cannot induce a switch to predation, but a long enough freeze (i.e., any $T > T_B^M$) triggers accommodation, which increases welfare (i.e., $W^A > W^M$).

[29] We focus on the generic case where $W^A \neq W_B^P(T_B^P)$. In the boundary case where $W^A = W_B^P(T_B^P)$, any $T \geq T_B^P$ is socially optimal.

4.4 Policy choice

Both the Williamson-Edlin and Baumol rules include laissez-faire as a particular case (i.e., $T = 1$), and both can also replicate a ban on predation: if monopolization arises under laissez-faire, a ban can be replicated with any $T > T_{WE}^{M}$ under the Williamson-Edlin rule, and with any $T > T_{B}^{M}$ under the Baumol rule. If instead predation arises under laissez-faire, a ban can be effectively replicated with $T = \infty$ under the Williamson-Edlin rule and with any $T > T_{B}^{P}$ under the Baumol rule.[30] Moreover, Propositions 5 and 7 show that both rules can dominate a ban on predation, by allowing for some predation when it is welfare enhancing. However, the two rules affect predation in different ways. As a result, either rule may dominate:

Proposition 8 (policy choice) *Assuming that the duration of the freeze is set optimally under the Williamson-Edlin and Baumol rules:*

(i) If accommodation prevails under laissez-faire, then:

- *the Baumol rule is uniquely socially optimal if* $\max\{k, \hat{\pi}_E^c\} \leq \pi_E^c < \hat{\pi}_E^c \underline{\lambda}/\lambda$ *and* $W_B^P\left(T_B^P\right) > W^A$*;*
- *laissez-faire is socially optimal otherwise.*

(ii) If instead predation prevails under laissez-faire, then:

- *the Baumol rule is uniquely socially optimal if* $W_B^P\left(T_B^P\right) > W^A$*;*
- *a ban on predation is socially optimal otherwise.*

(iii) Finally, if monopolization prevails under laissez-faire, then:

- *the Williamson-Edlin rule is uniquely socially optimal if* $\lambda \leq \underline{\lambda}$ *and* $W^P > W^A$*;*
- *a ban on predation is socially optimal otherwise.*

Proof. See Appendix B.8. ■

To see the underlying intuition, recall that both rules can ensure accommodation (namely, by setting a long enough freeze), and that monopolization is never desirable, as it yields the lowest welfare. It follows that the relative performance of a rule is driven by two considerations: first, whether it enables a switch to predation (when it dominates accommodation), and second, whether the rule can enhance welfare in

[30] As mentioned above, under the Williamson-Edlin rule an exclusionary equilibrium survives when $\lambda \leq \underline{\lambda}$, no matter how large T is. Yet, the frequency of predatory episodes goes to 0 when $T \rightarrow \infty$.

the predation equilibrium beyond what can be achieved with either laissez-faire or a ban.

When *accommodation* prevails under laissez-faire, the first consideration is the reason why the Baumol rule can outperform the Williamson-Edlin rule. Here the Williamson-Edlin rule has no impact on the equilibrium outcome, whereas the Baumol rule can trigger a switch to predation when $\max\{k, \hat{\pi}_E^c\} \leq \pi_E^c < \hat{\pi}_E^c \underline{\lambda}/\lambda$. As shown in Proposition 7, it is then optimal to choose a freeze duration slightly below T_B^P, which outperforms laissez-faire or a ban on predation if $W_B^P(T_B^P) > W^A$.

When *predation* prevails under laissez-faire, it is instead the second consideration that may enable the Baumol rule to outperform the Williamson-Edlin rule. Here, laissez-faire yields W^P, whereas a ban on predation yields W^A. By increasing the relative frequency of *competition* periods, the Williamson-Edlin rule increases welfare progressively from W^P to W^A and therefore cannot do better than either laissez-faire or a ban. By contrast, the Baumol rule can increase the relative frequency of *predation* periods; when $w^p > w^c$, expected welfare then not only increases with T, but tends to

$$\lim_{T \longrightarrow \infty} W_B^P(T) = \frac{w^p}{1-\delta} > \frac{w^c}{1-\delta} = W^A.$$

As predation survives as long as $T < T_B^P$, the Baumol rule outperforms the other three policies if $W_B^P(T_B^P) > W^A$.

Finally, when *monopolization* prevails under laissez-faire, the first consideration is again the reason why the Williamson-Edlin rule can here outperform the Baumol rule. Both rules can destabilize the monopolization equilibrium and thus dominate laissez-faire. However, the Baumol rule can only trigger a switch to accommodation, and thus cannot do better than a ban on predation. The Williamson-Edlin can instead induce a switch to predation whenever $\lambda \leq \underline{\lambda}$, which is preferable to a ban on predation whenever $W^P > W^A$.

Edlin et al. (2019) assess the implications of legal rules for predatory behavior, by running a series of lab experiments in which an incumbent and an entrant interact over four periods – the incumbent is alone in the first period, but a competitor can enter the market and stay in the following periods. Specifically, they consider a ban on below-cost pricing, a Baumol rule forbidding the incumbent to raise its prices if the entrant exits, and an Edlin rule that allows the incumbent to lower its price by at most 20% in case of entry. In their setting, the entrant has a higher cost than the incumbent, so above-cost predation is feasible. They find that, as expected, a ban of below-cost pricing has little effect on market outcomes. By contrast, the Baumol and Edlin rules encourage entry, as in our model. In particular, compared with laissez-faire, the Baumol rule induces incumbents to set higher prices in case of entry, whereas the Edlin rule induces them to set instead lower pre-entry prices, in order to retain their ability to compete effectively if entry occurs. Yet, as with the Baumol rule, post-entry prices are higher than under laissez-faire. These effects are not present in our parsimonious model, in which the incumbent cannot act strategically before entry, and cannot tailor its price post-entry. Interestingly, Edlin et al. find that the Edlin rule fosters entry more than the Baumol rule, but also generates the lowest welfare, the other two rules performing similarly to laissez-faire. The reason is that entry creates productive inefficiency, because fixed costs are duplicated and some output is now supplied by the higher-cost entrant.

5 Conclusion

We studied the scope for predation in an infinite-horizon setting with a persistent threat of entry. We first show that this scope depends critically on the entrant's beliefs about the incumbent's behavior. Indeed, entrants may be willing to bear losses in the short run if they expect that the incumbent will accommodate them in the future. This belief can in turn eliminate the incumbent's incentive to predate and thus be self-fulfilling. However, predation remains feasible if the entrants have pessimistic beliefs and expect the incumbent to keep predating in the future. Hence, the possibility of new entry does not eliminate the scope for predation if entrants' beliefs remain pessimistic.

Second, the scope for predation is also driven by the incumbent's own beliefs about rivals' future behavior. Predation is indeed more profitable, and thus more likely to occur, when the incumbent expects new entrants to stay out of the market. Other key factors which affect the scope for predation include the likelihood that new entrants appear in the future, the cost they incur when entering the market, the profit they expect under "normal competition," and the cost and benefits of predation from the incumbent's point of view – namely, the short-run sacrifice of profit due to predatory behavior and the long-run gain of profit following the rival's exit. Importantly, the scope for predation in our setting is completely independent of whether the incumbent's price is above or below cost. This suggests that the price-cost comparisons that play a key role in antitrust policy in U.S. and EU may be misguided.

Third, predation may be socially desirable if entry occurs sufficiently frequently, and consumers benefit from the incumbent's aggressive predatory behavior. Consequently, a complete ban on predation may not be desirable and in fact, optimal policy may even encourage predation in some cases.

Finally, we used our analysis to assess two "dynamic" legal rules that have been proposed to identify and mitigate predation: the Williamson-Edlin rule, which stipulates that following entry, the incumbent's pre-entry strategy should be frozen for a period of time; and the Baumol rule, which stipulates that the incumbent's predatory strategy should be frozen following an exit. We show that both rules may dominate a complete ban on predation, by adjusting the freeze period to deter exclusion when it is welfare reducing, but allowing predatory behavior when it is socially desirable.

Appendix

A Example: Stackelberg duopoly

To illustrate the assumed payoff structure, consider the following linear Stackelberg duopoly. I and E produce a homogeneous product and compete by setting quantities. The inverse demand function is $p = 1 - Q$, where $Q = q_I + q_E$ denotes the aggregate output. Both marginal costs are normalized to 0 and the fixed costs are $f_I < 1/8$ and $f_E < 1/16$.

In state $\mathcal{M}$, given I's output q_I, E's output, q_E, is given by the Cournot best-response:

$$R(q_I) \equiv \arg\max_{q_E} \{(1 - q_I - q_E) q_E - f_E\} = \frac{1 - q_I}{2}.$$

If in equilibrium a newborn E enters with probability $\eta \in [0, 1]$, the overall probability of entry is $\beta\eta$ and the resulting expected profit for I is

$$(1 - \beta\eta)(1 - q_I - \frac{1 - q_I}{2})q_I + \beta\eta(1 - q_I) q_I - f_I = \frac{1 + \beta\eta}{2}(1 - q_I) q_I - f_I.$$

This payoff is maximal at $q_I = q^m = 1/2$, regardless of the probability of entry.[31] If E does not enter, I earns the monopoly profit

$$\pi_I^m = \frac{1}{4} - f_I.$$

If E enters, it incurs an entry cost k and produces $q_E = R\left(q^l\right) = 1/4$; the resulting profits for I and E are then

$$\pi_I^c = \frac{1}{8} - f_I,$$

and $\pi_E^c - k$, where

$$\pi_E^c = \frac{1}{16} - f_E.$$

In state $\mathcal{C}$, if I accommodates entry, the Stackelberg equilibrium yields again the output levels $q_I = 1/2$ and $q_E = 1/4$. The resulting profits of I and E are thus given by π_I^c and π_E^c. Alternatively, I can predate by expanding its output to such an extent that E incurs a loss if it stays in the market. As our stylized model relies on a binary decision, to fix ideas suppose that I can only choose between using its existing plants with total output q^m, or activating an additional plant, thereby

[31] This comes from the fact that, in this linear model, the monopoly quantity q^m coincides with the quantity q^l chosen by a Stackelberg leader: $q^m = q^l = 1/2$.

expanding its total output to some $q_I^p \in \left(\underline{q}_I^p\left(f_E\right), 1\right)$, where[32]

$$\underline{q}_I^p\left(f_E\right) \equiv \max\left\{1 - 2\sqrt{f_E}, \frac{1}{2} + \frac{\sqrt{2}}{4}\right\} \left(> q_I^m\right).$$

The condition $q_I^p < 1$ ensures that E's response is positive: $q_E^p = R\left(q_I^p\right) > 0$. If E stays, its profit is therefore

$$\pi_E^p = \left(\frac{1 - q_I^p}{2}\right)^2 - f_E < 0,$$

where the inequality follows from the condition $q_I^p > 1 - 2\sqrt{f_E}$. If E exits, I's profit is

$$\pi_I^p = \left(1 - q_I^p\right) q_I^p - f_I < \pi_I^c \left(< \pi_I^m\right),$$

where the first inequality follows from the condition $q_I^p > 1/2 + \sqrt{2}/4$. If instead E stays, I's profit is

$$\underline{\pi}_I^p = \left(1 - q_I^p - q_E^p\right) q_I^p - f_I < \pi_I^p,$$

where the inequality stems from $q_E^p = R\left(q_I^p\right) > 0$.

Per-period consumer surplus is $Q^2/2$, where Q denotes total output. Hence, consumer surplus under monopoly, competition and (succesful) predation is thus given by:

$$CS^m = \frac{1}{8}, \qquad CS^c = \frac{9}{32}, \qquad CS^p = \frac{\left(q_I^p\right)^2}{2}.$$

In line with the spirit of our stylized model, let us assume that the welfare criterion W is of the form $W \equiv CS + \alpha\Pi$, where $\alpha \in [0, 1]$ denotes the weight placed on the industry profit $\Pi \equiv \pi_I + \pi_E$. In state $\mathcal{C}$, per-period welfare is therefore given by:

$$w^m = CS^m + \alpha\pi_I^m = \frac{1 + 2\alpha}{8} - \alpha f_I,$$

$$w^c = CS^c + \alpha\left(\pi_I^c + \pi_E^c\right) = \frac{9 + 6\alpha}{32} - \alpha\left(f_I + f_E\right),$$

and

$$w^p = CS^p + \alpha\pi_I^p = \left(\frac{1}{2} - \alpha\right)\left(q_I^p\right)^2 + \alpha q_I^p - \alpha f_I.$$

The expressions for state $\mathcal{M}$ are similar, except that when entry occurs, welfare is $w^c - \alpha k$ rather than w^c.

By construction, welfare under predation coincides with that under monopoly

[32] The lower bound $\underline{q}_I^p\left(f_E\right)$ is decreasing in f_E and ranges from $1/2 + \sqrt{2}/4 \simeq 0.85$ (for $\left(3 - 2\sqrt{2}\right)/32 \simeq 0.005 \leq f_E < 1/16 = 0.0625$) to 1 (for $f_E = 0$).

for $q_I^p = q^m$:

$$w^p|_{q_I^p = q^m} = \frac{1+2\alpha}{8} - \alpha f_I = w^m.$$

It moreover increases with output:

$$\frac{\partial w^p}{\partial q_I^p} = q_I^p - 2\alpha \left(q_I^p - \frac{1}{2} \right) > 1 - q_I^p > 0,$$

where the first inequality stems from $\alpha \leq 1$ and the second from $q_I^p < 1$. It follows that welfare is higher under predation than under monopoly:

$$w^p > w^m. \tag{4}$$

As the assumption $f_E < 1/16$ ensures that $\pi_E^c > 0$, we have:

$$w^c - w^m = CS^c + \alpha \left(\pi_I^c + \pi_E^c \right) - w^m > CS^c + \alpha \pi_I^c - w^m = \frac{5 - 4a}{32} > 0, \tag{5}$$

where the last inequality stems from $\alpha < 1$. If in addition hit-and-run entry is profitable ($\pi_E^c \geq k$), then the same reasoning implies that it is socially desirable; indeed, we then have:

$$\frac{w^c + w^p - \alpha k}{2} - w^m \geq \frac{CS^c + \alpha \pi_I^c - w^m}{2} > 0,$$

where the first inequality stems from (4) and the working assumption $\pi_E^c \geq k$, and the second one from (5).

Summing-up, this linear Stackelberg duopoly model provides a micro-foundation for the profit and welfare values used in our stylized setting. Specifically, for any $(f_I, f_E) \in [0, 1/8) \times (0, 1/16)$ and any $q_I^p \in \left(\underline{q}_I^p (f_E), 1 \right)$, the equilibrium profits satisfy the assumptions $\pi_I^m > \pi_I^c > \pi_I^p (> \underline{\pi}_I^p)$, $\min \{\pi_I^c, \pi_E^c\} > 0 > \pi_E^p$ and $w^m < \min \{w^c, w^p\}$. The two variables of interest used in Figures 1-3 (E's competitive profit, π_E, and the cost-benefit ratio, λ) are respectively driven by f_E and q_I^p:[33]

$$\pi_E^c = \frac{1}{16} - f_E \text{ and } \lambda = 1 - 8 q_I^p \left(1 - q_I^p \right).$$

It follows that, through appropriate choices of $f_E \in (0, 1/16)$ and $q_I^p \in \left(\underline{q}_I^p (f_E), 1 \right)$, π_E^c can take any value in $(0, 1/16)$ and λ can take any value in $\left(\hat{\lambda} (f_E), 1 \right)$, where $\hat{\lambda} (f_E) \equiv \max\{1 - 16\sqrt{f_E}(1 - 2\sqrt{f_E}), 0\}$.[34]

[33] π_E^c is clearly strictly decreasing in f_E, whereas λ is strictly increasing in q_I^p in the relevant range $q_I^p > \underline{q}_I^p$: $d\lambda / dq_I^p = 16 q_I^p - 8 > 0$, where the inequality stems from $q_I^p > \left(\underline{q}_I^p \geq q^m = \right) 1/2$.

[34] The lower bound $\hat{\lambda} (f_E)$ is decreasing in f_E for $f_E < 1/16$ and ranges from 0 (for $f_E \geq \left(3 - 2\sqrt{2} \right) / 32$) to 1 (for $f_E = 0$).

This micro-foundation is sufficiently flexible to allow for arbitrary positions of the key boundaries determining the existence of the different types of equilibria. Regarding the horizontal boundaries, an appropriate choice of $\delta \in (0,1)$ can yield any positive value for $\overline{\lambda}(= \delta / (1-\delta))$ and, for any given $\overline{\lambda}$ and associated δ, an appropriate choice of $\beta \in (0,1)$ can generate any value for $\underline{\lambda}\,(= (1-\beta)\,\delta / [1-(1-\beta)\,\delta])$ between 0 and $\overline{\lambda}$. As for the vertical boundaries, any k between 0 and $\pi_E^c / (1-\delta)\,(> \pi_E^c)$ is admissible – k can thus lie either below or above π_E^c, implying that either type of exclusionary equilibrium can arise. Finally, we can either have $\pi_I^p > 0$ (for f_I small enough, for any given $q_I^p \in (\underline{q}_I^p, 1)$) or $\pi_I^p < 0$ (if q_I^p is large enough, for any $f_I > 0$);[35] hence, I's predatory price can either be above or below average cost.[36]

B Proofs

B.1 Proof of Proposition 1

We consider the three types of equilibria in turn.

B.1.1 Accommodation

Consider a candidate equilibrium in which I never predates. E then enters in state $\mathcal{M}$, as $\pi_E^c > (1-\delta)\,k$, and stays in the market in state $\mathcal{C}$, as $\pi_E^c > 0$. Therefore, I's equilibrium continuation values in states $\mathcal{M}$ and $\mathcal{C}$, $V_{\mathcal{M}}^A$ and $V_{\mathcal{C}}^A$, satisfy:

$$V_{\mathcal{M}}^A = (1-\beta)\left(\pi_I^m + \delta V_{\mathcal{M}}^A\right) + \beta\left(\pi_I^c + \delta V_{\mathcal{C}}^A\right) \quad \text{and} \quad V_{\mathcal{C}}^A = \pi_I^c + \delta V_{\mathcal{C}}^A,$$

which leads to:

$$V_{\mathcal{M}}^A = \frac{\beta \pi_I^c + (1-\beta)(1-\delta)\,\pi_I^m}{[1-(1-\beta)\,\delta]\,(1-\delta)} \quad \text{and} \quad V_{\mathcal{C}}^A = \frac{\pi_I^c}{1-\delta}. \tag{6}$$

To complete the characterization, it suffices to check that I has no incentive to deviate to predation in state $\mathcal{C}$. Following such a deviation, if E stays it obtains a profit of π_E^p in the current period and, anticipating accommodation in the future, it expects a profit of π_E^c in every following period. Hence, E's expected continuation value from staying is given by

$$\pi_E^p + \frac{\delta \pi_E^c}{1-\delta}.$$

[35] For example, if $f_I = 0$, then $\pi_I^P > 0$ for any $q_I^p < 1$; if instead $q_I^p = 1$, then $\pi_I^P < 0$ for any $f_I > 0$.

[36] In this simple example, in which predation takes the form of costless output expansion, predation is socially beneficial whenever it is costly for I (i.e., $\pi_I^p < \pi_I^c$ and $w^p > w^c$). Introducing an additional fixed cost f_I^p of expanding output from q_I^m to q_I^p would allow for $\pi_I^p < \pi_I^c$ and $w^p < w^c$ (proofs available upon request).

It follows that, if $\pi_E^c \geq \hat{\pi}_E^c$, the deviation does not induce E to exit and is therefore unprofitable for I, as $\pi_I^c > \underline{\pi}_I^p$. In other words, accommodation is self-sustainable in that case.

If instead $\pi_E^c < \hat{\pi}_E^c$, I's deviation to predation does induce E to exit. Using (6), the effect of the deviation on I's payoff is given by:

$$\underbrace{\left(\pi_I^p + \delta V_{\mathcal{M}}^A\right)}_{\text{Value following deviation}} - \underbrace{\left(\pi_I^c + \delta V_{\mathcal{C}}^A\right)}_{\text{Value on the equilibrium path}} = \pi_I^p - \pi_I^c + \frac{(1-\beta)\,\delta\,(\pi_I^m - \pi_I^c)}{1-(1-\beta)\,\delta}$$
$$= (\pi_I^m - \pi_I^c)\,(\underline{\lambda} - \lambda)\,,$$

where the last equality stems from the definitions of λ and $\underline{\lambda}$. As $\pi_I^m > \pi_I^c$, the deviation is unprofitable if and only if $\lambda \geq \underline{\lambda}$.

B.1.2 Predation

Now consider a candidate equilibrium in which I predates in state $\mathcal{C}$. E then exits in state $\mathcal{C}$, as $\pi_E^p < 0$, but a newborn E enters (for one period) in state $\mathcal{M}$ as long as $\pi_E^c \geq k$. I's continuation values, $V_{\mathcal{M}}^P$ and $V_{\mathcal{C}}^P$, therefore satisfy:

$$V_{\mathcal{M}}^P = (1-\beta)\left(\pi_I^m + \delta V_{\mathcal{M}}^P\right) + \beta\left(\pi_I^c + \delta V_{\mathcal{C}}^P\right) \quad \text{and} \quad V_{\mathcal{C}}^P = \pi_I^p + \delta V_{\mathcal{M}}^P.$$

Solving yields:

$$V_{\mathcal{M}}^P = \frac{(1-\beta)\,\pi_I^m + \beta\,(\pi_I^c + \delta\pi_I^p)}{(1+\beta\delta)\,(1-\delta)} \quad \text{and} \quad V_{\mathcal{C}}^P = \frac{(1-\beta)\,\delta\pi_I^m + \beta\delta\pi_I^c + [1-(1-\beta)\delta]\pi_I^p}{(1+\beta\delta)\,(1-\delta)}. \tag{7}$$

To check that this is indeed an equilibrium, consider a one-period deviation of I to accommodation in state $\mathcal{C}$. As $\pi_E^c > 0$, E stays in the market during the deviation period, but exits next period when I reverts to predation, as $\pi_E^p < 0$. Using (7), the effect of the deviation on I's payoff is:

$$\underbrace{\left(\pi_I^c + \delta V_{\mathcal{C}}^P\right)}_{\text{Value following deviation}} - \underbrace{\left(\pi_I^p + \delta V_{\mathcal{M}}^P\right)}_{\text{Value on the equilibrium path}} = \pi_I^c - \pi_I^p - \frac{\delta\,[(1-\beta)\,(\pi_I^m - \pi_I^c) + \pi_I^c - \pi_I^p]}{1+\beta\delta}$$
$$= \frac{[1-(1-\beta)\delta](\pi_I^m - \pi_I^c)}{1+\beta\delta}\,(\lambda - \underline{\lambda})\,.$$

The deviation is therefore unprofitable if and only if $\lambda \leq \underline{\lambda}$.

B.1.3 Monopolization

Finally, consider a candidate equilibrium in which I predates in state $\mathcal{C}$, and newborn E's do not enter in state $\mathcal{M}$, which requires that $\pi_E^c \leq k$. I's continuation values, $V_{\mathcal{M}}^{M}$ and $V_{\mathcal{C}}^{M}$, then satisfy:

$$V_{\mathcal{M}}^{M} = \pi_I^m + \delta V_{\mathcal{M}}^{M} \quad \text{and} \quad V_{\mathcal{C}}^{M} = \pi_I^p + \delta V_{\mathcal{M}}^{M}.$$

Solving yields:

$$V_{\mathcal{M}}^{M} = \frac{\pi_I^m}{1-\delta} \quad \text{and} \quad V_{\mathcal{C}}^{M} = \pi_I^p + \frac{\delta \pi_I^m}{1-\delta}. \tag{8}$$

Using these expressions, the net effect of a one-period deviation to accommodation in state $\mathcal{C}$ on I's payoff is:

$$\begin{aligned}\underbrace{\left(\pi_I^c + \delta V_{\mathcal{C}}^{M}\right)}_{\text{Value following deviation}} - \underbrace{\left(\pi_I^p + \delta V_{\mathcal{M}}^{M}\right)}_{\text{Value on the equilibrium path}} &= \pi_I^c - \pi_I^p - \delta\left(\left(\pi_I^m - \pi_I^c\right) + \left(\pi_I^c - \pi_I^p\right)\right) \\ &= (1-\delta)\left(\pi_I^m - \pi_I^c\right)\left(\lambda - \overline{\lambda}\right).\end{aligned}$$

The deviation is therefore unprofitable if and only if $\lambda \leq \overline{\lambda}$.

B.2 Proof of Proposition 2

We show below that, whenever an exclusionary equilibrium coexists with the accommodation equilibrium, I obtains higher continuation values (in both states) in the exclusionary equilibrium. We first consider the case where exclusion takes the form of predation, before turning to monopolization.

B.2.1 Predation vs. accommodation

First consider state $\mathcal{M}$. Using (6) and (7), we have:

$$\begin{aligned}V_{\mathcal{M}}^{P} - V_{\mathcal{M}}^{A} &= \frac{1}{1-\delta}\left[\frac{(1-\beta)\,\pi_I^m + \beta\left(\pi_I^c + \delta\pi_I^p\right)}{1+\beta\delta} - \frac{\beta\pi_I^c + (1-\beta)(1-\delta)\,\pi_I^m}{1-(1-\beta)\,\delta}\right] \\ &= \frac{\beta\delta}{(1-\delta)(1+\beta\delta)} \frac{(1-\beta)\delta(\pi_I^m - \pi_I^c) - [1-(1-\beta)\delta](\pi_I^c - \pi_I^p)}{1-(1-\beta)\,\delta} \\ &= \frac{\beta\delta\left(\pi_I^m - \pi_I^c\right)}{(1-\delta)(1+\beta\delta)}\left(\underline{\lambda} - \lambda\right) \geq 0,\end{aligned}$$

where the inequality follows because a predation equilibrium exists only if $\lambda \leq \underline{\lambda}$.

Similarly, in state $\mathcal{C}$:

$$\begin{aligned}V_{\mathcal{C}}^{P} - V_{\mathcal{C}}^{A} &= \frac{1}{1-\delta}\left\{\frac{(1-\beta)\,\delta\pi_I^m + \beta\delta\pi_I^c + [1-(1-\beta)\,\delta]\pi_I^p}{1+\beta\delta} - \pi_I^c\right\} \\ &= \frac{(1-\beta)\,\delta\left(\pi_I^m - \pi_I^c\right) - [1-(1-\beta)\delta]\left(\pi_I^c - \pi_I^p\right)}{(1-\delta)(1+\beta\delta)} \\ &= \frac{[1-(1-\beta)\,\delta]\left(\pi_I^m - \pi_I^c\right)}{(1-\delta)(1+\beta\delta)}\left(\underline{\lambda} - \lambda\right) \geq 0.\end{aligned}$$

Hence, in both states I prefers the predation equilibrium over the accommodation equilibrium whenever they coexist.

B.2.2 Monopolization vs. accommodation

Consider state $\mathcal{M}$. Using (6) and (8), and recalling that $\pi_I^m > \pi_I^c$, we have:

$$\begin{aligned} V_{\mathcal{M}}^M - V_{\mathcal{M}}^A &= \frac{1}{1-\delta}[\pi_I^m - \frac{\beta\pi_I^c + (1-\beta)(1-\delta)\pi_I^m}{1-(1-\beta)\delta}] \\ &= \frac{\beta(\pi_I^m - \pi_I^c)}{(1-\delta)[1-(1-\beta)\delta]} > 0. \end{aligned}$$

Similarly, in state $\mathcal{C}$:

$$\begin{aligned} V_{\mathcal{C}}^M - V_{\mathcal{C}}^A &= \frac{(1-\delta)\pi_I^p + \delta\pi_I^m - \pi_I^c}{1-\delta} \\ &= \frac{\delta(\pi_I^m - \pi_I^c) - (1-\delta)(\pi_I^c - \pi_I^p)}{1-\delta} \\ &= (\pi_I^m - \pi_I^c)\left(\overline{\lambda} - \lambda\right) \geq 0, \end{aligned}$$

where the inequality follows because a monopolization equilibrium exists only if $\lambda \leq \overline{\lambda}$.

Hence, in both states I prefers the monopolization equilibrium over the accommodation equilibrium whenever they coexist.

B.3 Proof of Proposition 3

Part (i) follows directly from the observation that a ban on predation has no effect when accommodation already prevails.

If instead predation initially prevails, a ban on predation changes total discounted welfare from W^P, given by (1), to $W^A = w^c/(1-\delta)$; part (ii) then follows from:

$$W^A - W^p = \frac{w^c - (1-\beta)w^m - \beta(w^p - \alpha k)}{(1+\beta)(1-\delta)}.$$

Finally, if monopolization initially prevails, part (iii) stems from the fact that a ban on predation improves total discounted welfare from $W^M = w^m/(1-\delta) < w^c/(1-\delta) = W^A$ to W^A.

B.4 Proof of Proposition 4

We first consider the three types of equilibria under the Williamson-Edlin rule, before drawing the implications for the impact of the rule.

B.4.1 Accommodation

In an accommodation equilibrium, I never predates; hence the Williamson-Edlin rule has no bite on the equilibrium path and the continuation values $V_{\mathcal{M}}^{A}$ and $V_{\mathcal{C}}^{A}$ remain unchanged. Furthermore, in state $\mathcal{C}$, the rule has no effect on firms' payoffs following a one-period deviation to predation. Thus, if $\pi_E^c \geq \hat{\pi}_E^c$, accommodation remains self-sustainable, as the deviation fails to trigger exit and is thus unprofitable. If instead $\pi_E^c < \hat{\pi}_E^c$, the deviation triggers exit and, as before, is unprofitable if and only if $\lambda \geq \underline{\lambda}$.

B.4.2 Predation

Consider now a predation equilibrium. As before, when I predates in state $\mathcal{C}$, E exits as $\pi_E^p < 0$. For the equilibrium to exist, a newborn E must be willing to enter in state $\mathcal{M}$, which is the case if it covers its cost of entry during the T periods of freeze in which it is accommodated:

$$k \leq \left(1 + \delta + ... + \delta^{T-1}\right) \pi_E^c = \frac{1 - \delta^T}{1 - \delta} \pi_E^c \quad \Longleftrightarrow \quad \pi_E^c \geq \underbrace{\frac{1 - \delta}{1 - \delta^T}}_{\psi(T)} k.$$

As $\psi(T)$ is strictly decreasing in T and tends to 0 as T goes to infinity, this inequality amounts to $T \geq T_{WE}^M$, where T_{WE}^M is defined implicitly by $\pi_E^c = \psi(T) k$.

As a newborn E enters and remains in the market during the T periods of freeze, I's continuation values, $\hat{V}_{\mathcal{M}}^P$ and $\hat{V}_{\mathcal{C}}^P$, now satisfy:

$$\hat{V}_{\mathcal{M}}^P = (1 - \beta) (\pi_I^m + \delta \hat{V}_{\mathcal{M}}^P) + \beta (\frac{1 - \delta^T}{1 - \delta} \pi_I^c + \delta^T \hat{V}_{\mathcal{C}}^P) \quad \text{and} \quad \hat{V}_{\mathcal{C}}^P = \pi_I^p + \delta \hat{V}_{\mathcal{M}}^P.$$

Solving yields:

$$\begin{aligned} \hat{V}_{\mathcal{M}}^P &= \frac{(1 - \beta) \pi_I^m + \beta \frac{1 - \delta^T}{1 - \delta} \pi_I^c + \beta \delta^T \pi_I^p}{1 - (1 - \beta) \delta - \beta \delta^{T+1}}, \\ \hat{V}_{\mathcal{C}}^P &= \frac{(1 - \beta) \delta \pi_I^m + \beta \delta \frac{1 - \delta^T}{1 - \delta} \pi_I^c + [1 - (1 - \beta) \delta] \pi_I^p}{1 - (1 - \beta) \delta - \beta \delta^{T+1}}. \end{aligned}$$

To ensure that predation is an equilibrium, I's equilibrium payoff, $\pi_I^p + \delta \hat{V}_{\mathcal{M}}^P$, must exceed its corresponding payoff under a deviation to accommodation in state $\mathcal{C}$, $\pi_I^c + \delta \hat{V}_{\mathcal{C}}^P$, which amounts to:

$$\begin{aligned} \pi_I^c - \pi_I^p &\leq \delta (\hat{V}_{\mathcal{M}}^P - \delta \hat{V}_{\mathcal{C}}^P) \\ &= \delta \frac{(1 - \delta) (1 - \beta) (\pi_I^m - \pi_I^c) + [1 - (1 - \beta) \delta - \beta \delta^T] (\pi_I^c - \pi_I^p)}{1 - (1 - \beta) \delta - \beta \delta^{T+1}}. \end{aligned}$$

Rearranging terms yields:

$$(1-\delta)[1-(1-\beta)\delta](\pi_I^c-\pi_I^p) \leq \delta(1-\delta)(1-\beta)(\pi_I^m-\pi_I^c)$$
$$\iff \qquad \lambda = \frac{\pi_I^c-\pi_I^p}{\pi_I^m-\pi_I^c} \leq \frac{(1-\beta)\delta}{1-(1-\beta)\delta} = \underline{\lambda}.$$

B.4.3 Monopolization

For a monopolization equilibrium to exist, a newborn E should not find it profitable to enter and stay in the market during the T periods of freeze; hence, we must have that

$$\frac{1-\delta^T}{1-\delta}\pi_E^c \leq k \qquad \iff \qquad \pi_E^c \leq \underbrace{\frac{1-\delta}{1-\delta^T}}_{\psi(T)}k,$$

which is equivalent to $T \leq T_{WE}^M$ as $\psi'(T) < 0$. As newborn E's do not enter, the Williamson-Edlin rule has no bite on the equilibrium path, so the continuation values $V_{\mathcal{M}}^M$ and $V_{\mathcal{C}}^M$ remain unchanged. Furthermore, in state $\mathcal{C}$ the rule has no effect on I's payoff from a one-period deviation to accommodation: the deviation induces E to stay and thus yields as before a total discounted payoff of $\pi_I^c + \delta V_{\mathcal{C}}^M$. Therefore the deviation is unprofitable if and only if $\lambda \leq \overline{\lambda}$.

B.4.4 Impact of the Williamson-Edlin rule

It follows from the above analysis that, under Assumption A, the rule is irrelevant when the accommodation equilibrium prevails under laissez-faire.

When instead the predation equilibrium prevails under laissez-faire, introducing the rule does not affect the type of equilibrium but only increases the frequency of competition periods.

Finally, when the monopolization equilibrium prevails under laissez-faire, the rule is irrelevant if $T \leq T_{WE}^M$; if instead $T > T_{WE}^M$, the rule induces a switch from monopolization to accommodation if $\lambda > \underline{\lambda}$ and to the modified predation equilibrium otherwise.

B.5 Proof of Proposition 5

From Proposition 4, the Williamson-Edlin rule is irrelevant when the accommodation equilibrium prevails under laissez-faire; total discounted welfare then remains $W^A = w^c/(1-\delta)$.

To proceed further, we first compute the expected welfare generated by the predation equilibrium. Let $\mathcal{F}_\tau$ denote the state in which there *remain* $T-\tau$ periods of freeze (including the current one), for every $\tau \in \{1, ..., T-1\}$;[37] with this convention, $\mathcal{F}_1$ corresponds to the first period of freeze (after the period of entry) and $\mathcal{F}_{T-1}$ to its last period. Upon entry, the sequence of states is thus $\mathcal{M} \to \mathcal{F}_1 \to \ldots \to \mathcal{F}_{T-1} \to \mathcal{C}$. It follows that the long-run equilibrium probabilities of states $\mathcal{M}$, $\mathcal{C}$, and $\mathcal{F}_\tau$, $\mu_{\mathcal{M}}$, $\mu_{\mathcal{C}}$, and $\mu_{\mathcal{F}_\tau}$ satisfy $\mu_{\mathcal{C}} = \mu_{\mathcal{F}_{T-1}} = ... = \mu_{\mathcal{F}_1} = \mu_{\mathcal{M}}\beta$, and are thus given by

$$\mu_{\mathcal{C}} = \frac{\beta}{1+\beta T} \text{ and } \mu_{\mathcal{M}} = \frac{1}{1+\beta T}. \tag{9}$$

As expected welfare is $(1-\beta)\, w^m + \beta\,(w^c - \alpha k)$ in state $\mathcal{M}$, w^p in state $\mathcal{C}$, and w^c in states $\{\mathcal{F}_\tau\}_{\tau=1,\ldots,T-1}$, total expected discounted welfare in the predation equilibrium under the Williamson-Edlin rule, $W^P_{WE}(T)$, can be expressed as:

$$\begin{aligned} W^P_{WE}(T) &\equiv \mu_{\mathcal{M}} \frac{(1-\beta)\, w^m + \beta\,(w^c - \alpha k)}{1-\delta} + \mu_{\mathcal{C}} \frac{w^p}{1-\delta} + \textstyle\sum_{\tau=1}^{T-1} \mu_{\mathcal{F}_\tau} \frac{w^c}{1-\delta} \\ &= \frac{(1-\beta) w^m + \beta\,(w^p - \alpha k) + \beta T w^c}{(1+\beta T)(1-\delta)} \\ &= W^A + \frac{1+\beta}{1+\beta T}\left(W^P - W^A\right). \end{aligned}$$

It follows that, as T increases from 1 to ∞, $W^P_{WE}(T)$ varies monotonically from W^P to W^A.

If predation prevails under laissez-faire, from Proposition 4 it still prevails under the rule; hence, laissez-faire (i.e., $T=1$) is uniquely optimal if $W^P > W^A$. If instead $W^P < W^A$, a ban on predation (i.e., $T=\infty$) is uniquely optimal. Finally, in the boundary case where $W^P = W^A$, any T is optimal.

If instead monopolization prevails under laissez-faire, Proposition 4 implies that it survives as long as $T \le T^M_{WE}$, and otherwise switches to either accommodation (if $\lambda > \underline{\lambda}$) or predation (if $\lambda \le \underline{\lambda}$); as $W^M < W^A$ and $W^M < W^P_{WE}(T)$ for any $T \ge 1$, it is always optimal to induce such a switch. If $\lambda > \underline{\lambda}$, any $T > T^M_{WE}$ is optimal and yields W^A. If $\lambda \le \underline{\lambda}$, the precise choice of T depends again on whether a ban on predation is desirable. If $W^P > W^A$, setting T slightly above T^M_{WE} is uniquely optimal and (almost) yields $W^P_{WE}\left(T^M_{WE}\right)$. If instead $W^A > W^P$, a ban on predation (i.e., $T=\infty$) is uniquely optimal. Finally, in the boundary case where $W^A = W^P$, any $T > T^M_{WE}$ yields $W^P_{WE}(T) = W^A$ and is thus optimal.

B.6 Proof of Proposition 6

We first consider the various types of equilibria that arise under the Baumol rule, before drawing the implications for the impact of the rule.

[37] Recall that $T=1$ refers to the baseline case; we thus focus here on $T \ge 2$.

B.6.1 Accommodation

In an accommodation equilibrium, I never predates, so the Baumol rule has no bite on the equilibrium path; the continuation values $V_{\mathcal{M}}^{A}$ and $V_{\mathcal{C}}^{A}$ thus remain unchanged. However, if I deviates and predates in state $\mathcal{C}$, it now must continue do so for T periods rather than just one period. Hence, accommodation remains self-sustainable (i.e., I's deviation fails to trigger exit) if

$$\frac{1-\delta^{T}}{1-\delta}\pi_{E}^{p}+\frac{\delta^{T}}{1-\delta}\pi_{E}^{c}\geq 0.$$

Rearranging and multiplying both sides by $\frac{1-\delta}{\delta}$ yields:

$$\frac{1-\delta}{\delta}\frac{\delta^{T}}{1-\delta^{T}}\pi_{E}^{c}\geq-\frac{1-\delta}{\delta}\pi_{E}^{p}\qquad\Longleftrightarrow\qquad\phi\left(T\right)\pi_{E}^{c}\geq\hat{\pi}_{E}^{c}.$$

Noting that $\phi\left(T\right)$ is strictly decreasing in T and tends to 0 as T goes to infinity, it follows that accommodation remains self-sustainable as long as $T\leq T_{B}^{A}$, where T_{B}^{A} is implicitly defined by $\phi\left(T_{B}^{A}\right)\pi_{E}^{c}=\hat{\pi}_{E}^{c}$.

If instead $T>T_{B}^{A}$, I's one-period deviation to predation triggers exit and its net effect on I's payoff is thus:

$$\begin{aligned}
&\underbrace{\left[\frac{(1-\delta^{T})\pi_{I}^{p}}{1-\delta}+\delta^{T}V_{\mathcal{M}}^{A}\right]}_{\text{Value following deviation}}-\underbrace{\left[\frac{(1-\delta^{T})\pi_{I}^{c}}{1-\delta}+\delta^{T}V_{\mathcal{C}}^{A}\right]}_{\text{Value on the equilibrium path}}\\
&\qquad=\frac{\left(1-\beta\right)\delta^{T}\left(\pi_{I}^{m}-\pi_{I}^{c}\right)}{1-\left(1-\beta\right)\delta}-\frac{\left(1-\delta^{T}\right)\left(\pi_{I}^{c}-\pi_{I}^{p}\right)}{1-\delta}\\
&\qquad=\frac{\left(1-\delta^{T}\right)\left(\pi_{I}^{m}-\pi_{I}^{c}\right)}{1-\delta}\left[\phi\left(T\right)\underline{\lambda}-\lambda\right],
\end{aligned}$$

where the second equality follows from $\lambda=\frac{\pi_{I}^{c}-\pi_{I}^{p}}{\pi_{I}^{m}-\pi_{I}^{c}}$, $\underline{\lambda}=\frac{(1-\beta)\delta}{1-(1-\beta)\delta}$, and $\phi\left(T\right)=\delta^{T-1}\frac{1-\delta}{1-\delta^{T}}$. Hence, the deviation is unprofitable, implying that the accommodation equilibrium survives if and only if $\lambda\geq\phi\left(T\right)\underline{\lambda}$; as $\phi\left(T\right)$ is decreasing in T, this amounts to $T\geq T_{B}^{P}$, where T_{B}^{P} is defined implicitly by $\phi\left(T_{B}^{P}\right)\underline{\lambda}=\lambda$.

B.6.2 Predation

If I predates in equilibrium, E exits in state $\mathcal{C}$ just as before. For a predation equilibrium to exist, a newborn E must be willing to enter the market for one period, which requires $\pi_{E}^{c}\geq k$. As the rule requires I to keep predating for T periods, I's continuation values, $\tilde{V}_{\mathcal{M}}^{P}$ and $\tilde{V}_{\mathcal{C}}^{P}$, are such that:

$$\tilde{V}_{\mathcal{M}}^{P}=\left(1-\beta\right)\left(\pi_{I}^{m}+\delta\tilde{V}_{\mathcal{M}}^{P}\right)+\beta(\pi_{I}^{c}+\delta\tilde{V}_{\mathcal{C}}^{P})\quad\text{and}\quad\tilde{V}_{\mathcal{C}}^{P}=\frac{1-\delta^{T}}{1-\delta}\pi_{I}^{p}+\delta^{T}\tilde{V}_{\mathcal{M}}^{P}.$$

Solving yields:

$$\tilde{V}_{\mathcal{M}}^{P} = \frac{(1-\beta)(1-\delta)\pi_I^m + \beta(1-\delta)\pi_I^c + \beta\delta\left(1-\delta^T\right)\pi_I^p}{\left[1-\delta+\beta\delta\left(1-\delta^T\right)\right](1-\delta)},$$

$$\tilde{V}_{\mathcal{C}}^{P} = \frac{(1-\beta)(1-\delta)\delta^T\pi_I^m + \beta(1-\delta)\delta^T\pi_I^c + \left[1-(1-\beta)\delta\right]\left(1-\delta^T\right)\pi_I^p}{\left[1-\delta+\beta\delta\left(1-\delta^T\right)\right](1-\delta)}.$$

Predation is an equilibrium if it is immune to I deviating for one period to accommodation in state $\mathcal{C}$. The effect of such a deviation on I's payoff is:

$$\begin{aligned}
\underbrace{\left(\pi_I^c + \delta\tilde{V}_{\mathcal{C}}^{P}\right)}_{\text{Value following deviation}} \quad - \quad \underbrace{\tilde{V}_{\mathcal{C}}^{P}}_{\text{Value on the equilibrium path}} & \\
&= \pi_I^c - \frac{\beta(1-\delta)\delta^T\pi_I^c}{1-\delta+\beta\delta\left(1-\delta^T\right)} \\
&\quad - \frac{(1-\beta)(1-\delta)\delta^T\pi_I^m + \left[1-(1-\beta)\delta\right]\left(1-\delta^T\right)\pi_I^p}{1-\delta+\beta\delta\left(1-\delta^T\right)} \\
&= \frac{\left[1-(1-\beta)\delta\right]\left(1-\delta^T\right)\left(\pi_I^m-\pi_I^c\right)}{1-\delta+\beta\delta\left(1-\delta^T\right)} \\
&\qquad \times \left[\frac{\pi_I^c-\pi_I^p}{\pi_I^m-\pi_I^c} - \frac{(1-\delta)\delta^{T-1}}{1-\delta^T}\frac{(1-\beta)\delta}{1-(1-\beta)\delta}\right] \\
&= \frac{\left[1-(1-\beta)\delta\right]\left(1-\delta^T\right)\left(\pi_I^m-\pi_I^c\right)}{1-\delta+\beta\delta\left(1-\delta^T\right)}\left[\lambda - \phi(T)\underline{\lambda}\right].
\end{aligned}$$

Hence, the deviation is unprofitable if and only $\lambda \leq \phi(T)\underline{\lambda}$, which amounts to $T \leq T_B^P$.

B.6.3 Monopolization

For a monopolization equilibrium to exist, hit-and-run entry must be unprofitable: $\pi_E^c \leq k$. I's continuation values, $\tilde{V}_{\mathcal{M}}^{M}$ and $\tilde{V}_{\mathcal{C}}^{M}$, then satisfy:

$$\tilde{V}_{\mathcal{M}}^{M} = \pi_I^m + \delta\tilde{V}_{\mathcal{M}}^{M} \quad \text{and} \quad \tilde{V}_{\mathcal{C}}^{M} = \frac{1-\delta^T}{1-\delta}\pi_I^p + \delta^T\tilde{V}_{\mathcal{M}}^{M}.$$

Solving yields:

$$\tilde{V}_{\mathcal{M}}^{M} = \frac{\pi_I^m}{1-\delta} \quad \text{and} \quad \tilde{V}_{\mathcal{C}}^{M} = \frac{1-\delta^T}{1-\delta}\pi_I^p + \frac{\delta^T}{1-\delta}\pi_I^m.$$

By deviating to accommodation in state $\mathcal{C}$, I postpones predation by one period; the resulting effect on I's payoff is thus:

$$\underbrace{\left(\pi_I^c + \delta\tilde{V}_{\mathcal{C}}^{M}\right)}_{\text{Value following deviation}} \quad - \quad \underbrace{\tilde{V}_{\mathcal{C}}^{M}}_{\text{Value on the equilibrium path}} \quad = \pi_I^c - (1-\delta)\left(\frac{1-\delta^T}{1-\delta}\pi_I^p + \frac{\delta^T}{1-\delta}\pi_I^m\right)$$

$$= (1-\delta^T)(\pi_I^m - \pi_I^c)[\lambda - \phi(T)\overline{\lambda}],$$

where the second equality follows from $\lambda = \frac{\pi_I^c - \pi_I^p}{\pi_I^m - \pi_I^c}$, $\overline{\lambda} = \frac{\delta}{1-\delta}$, and $\phi(T) = \delta^{T-1}\frac{1-\delta}{1-\delta^T}$. Hence, the deviation is unprofitable if and only if $\lambda \leq \phi(T)\overline{\lambda}$. As $\phi(T)$ is strictly decreasing with T and tends to 0 as T goes to infinity, it follows that accommodation remains self-sustainable as long as $T \leq T_B^M$, where T_B^M is implicitly defined by $\phi(T_B^M)\overline{\lambda} = \lambda$.

B.6.4 Impact of the Baumol rule

The above analysis implies that when the monopolization equilibrium prevails under laissez-faire, it survives as long as $T \leq T_B^M$. When instead $T > T_B^M$, the rule induces a switch from monopolization to accommodation.

Likewise, when the predation equilibrium prevails under laissez-faire, it also survives (albeit with higher frequency of predation periods) when $T \leq T_B^P$, but when $T > T_B^P$, the rule induces a switch from predation to accommodation.

Suppose now that accommodation prevails under laissez-faire, which requires either $\lambda \geq \underline{\lambda}$, or $\pi_E^c \geq \hat{\pi}_E^c$. If $\lambda \geq \underline{\lambda}$, then $\lambda \geq \phi(T)\underline{\lambda}$, as $\phi(T) \leq 1$ for $T \geq 1$; hence, accommodation continues to prevail when the rule is in place. If instead $\lambda < \underline{\lambda}$ but $\pi_E^c \geq \hat{\pi}_E^c$, the accommodation equilibrium survives unless accommodation is no longer self-sustainable and I has an incentive to deviate to predation; that is, unless $T \in (T_B^A, T_B^P)$. As $\phi(T)$ is decreasing in T, this condition implies:

$$\frac{\lambda}{\underline{\lambda}} = \phi(T_P^B) < \phi(T) < \phi(T_B^A) = \frac{\hat{\pi}_E^c}{\pi_E^c},$$

which in turn implies that $\pi_E^c < \hat{\pi}_E^c \underline{\lambda}/\lambda$. That is, the accommodation equilibrium survives unless $\hat{\pi}_E^c \leq \pi_E^c < \hat{\pi}_E^c \underline{\lambda}/\lambda$ and $T_B^A < T < T_B^P$.[38] In that case, the rule induces a switch to an exclusionary equilibrium, which, as seen above, is the monopolization equilibrium if $\pi_E^c < k$, and the modified predation equilibrium otherwise.

B.7 Proof of Proposition 7

Suppose first that the monopolization equilibrium prevails under laissez-faire. From Proposition 6, the Baumol rule does not affect this equilibrium if $T \leq T_B^M$, in which case expected welfare remains equal to W^M, but induces a switch to accommodation if $T > T_B^M$, which increases welfare to W^A. It is therefore optimal to choose any $T > T_B^M$.

[38] Note that $\pi_E^c < \hat{\pi}_E^c \underline{\lambda}/\lambda$ and $\pi_E^c \geq \hat{\pi}_E^c$ together imply $\lambda < \underline{\lambda}$.

To proceed further, we first compute the expected welfare in a predation equilibrium under the Baumol rule. Let $\mathcal{F}_\tau$, where $\tau \in \{1, ..., T-1\}$, denote (as before) the state in which there remains $T-\tau$ periods of freeze (including the current one); upon entry, the sequence of states is now given by $\mathcal{M} \to \mathcal{C} \to \mathcal{F}_1 \to \ldots \to \mathcal{F}_{T-1} \to \mathcal{M}$, where $\mathcal{F}_1$ corresponds again to the first period of freeze and $\mathcal{F}_{T-1}$ to its last period. The long-run probabilities still satisfy $\mu_\mathcal{C} = \mu_{\mathcal{F}_{T-1}} = ... = \mu_{\mathcal{F}_1} = \mu_\mathcal{M}\beta$, as under the Williamson-Edlin rule, and thus remain given by (9).

Expected welfare is $(1-\beta)\, w^m + \beta\,(w^c - \alpha k)$ in state $\mathcal{M}$ and w^p in state $\mathcal{C}$, but is now equal to w^p in states $\{\mathcal{F}_\tau\}_{\tau=1,\ldots,T-1}$ as well; hence, total expected discounted welfare can be expressed as:

$$
\begin{aligned}
W_B^P(T) &\equiv \mu_\mathcal{M}\frac{(1-\beta)\, w^m + \beta\,(w^c - \alpha k)}{1-\delta} + \mu_\mathcal{C}\frac{w^p}{1-\delta} + \textstyle\sum_{\tau=1}^{T-1}\mu_{\mathcal{F}_\tau}\dfrac{w^p}{1-\delta} \\
&= \frac{(1-\beta)\, w^m + \beta\,(w^c - \alpha k) + \beta T w^p}{(1+\beta T)\,(1-\delta)}.
\end{aligned}
$$

Compared with competition periods, welfare is strictly lower in monopoly periods (i.e., $w^m < w^c$) and weakly lower in case of entry (by $-\alpha k \leq 0$). Hence, a predation equilibrium can be socially preferable to accommodation (i.e., $W_B^P(T) \geq W^A$) only if predation periods yield a strictly higher welfare than competition (i.e., $w^p > w^c$). Furthermore, in that case $W_B^P(T)$ strictly increases with T.[39]

Suppose now that the predation equilibrium prevails under laissez-faire. From Proposition 6, it survives (with higher frequency of predation periods) if $T \leq T_B^P$, otherwise the rule induces a switch to accommodation. As just shown, a predation equilibrium can be socially preferable to accommodation only if $w^p > w^c$, in which case welfare is strictly increasing in T. It follows that setting $T = T_B^P$ is uniquely optimal if $W_B^P(T_B^P) > W^A$, whereas any $T > T_B^P$ is optimal if instead $W_B^P(T_B^P) < W^A$ – in the boundary case where $W_B^P(T_B^P) = W^A$, any $T \geq T_B^P$ is optimal.

Finally suppose that the accommodation equilibrium prevails under laissez-faire. From Proposition 6, the rule is irrelevant unless $\lambda < \underline{\lambda}\min\{1, \hat{\pi}_E^c/\pi_E^c\}$, in which case it induces a switch to predation if $T_B^A < T < T_B^P$ (where $T_B^A > 1$). As shown above, a predation equilibrium can be socially preferable to accommodation only if $w^p > w^c$, in which case welfare is strictly increasing in T. Hence, it is optimal to choose a duration slightly below T_B^P if $W_B^P(T_B^P) > W^A$; if instead $W_B^P(T_B^P) \leq W^A$, laissez-faire (i.e., $T = 1$) is optimal, as well as any $T \notin (T_B^A, T_B^P)$.

[39] The derivative of $W_B^P(T)$ is positive whenever $w^p > (1-\beta)\, w^m + \beta\,(w^c - \alpha k)$, where the right-hand side is strictly lower than w^c.

B.8 Proof of Proposition 8

If accommodation prevails under laissez-faire, the Williamson-Edlin rule is irrelevant. By contrast, if $\min\{k, \hat{\pi}_E^c\} \leq \pi_E^c < \hat{\pi}_E^c \underline{\lambda}/\lambda$, the Baumol rule can induce a switch to predation, which is socially beneficial if $W_B^P\left(T_B^P\right) > W^A$.

If instead monopolization prevails under laissez-faire, both rules can effectively impose a switch to accommodation with long enough freezes; as $W^A > W^M$, doing so dominates laissez-faire. However, unlike the Baumol rule, the Williamson-Edlin rule may also induce a switch to predation; this occurs when $\lambda \leq \underline{\lambda}$, and strictly dominates switching to accommodation if $W^P > W^A$, in which case the Williamson-Edlin rule is the only optimal policy.

Finally, if predation prevails under laissez-faire, the Williamson-Edlin rule cannot do better than either laissez-faire or a ban of predation. By contrast, from Proposition 7, the Baumol rule dominates both of these policies whenever $W_B^P\left(T_B^P\right) > W^A$, which occurs if $w^p > w^c$ and T_B^P is large enough; recalling that T_B^P is implicitly defined by $\phi(T_P^B)\underline{\lambda} = \lambda$, where $\phi\left(T\right)$ is decreasing in T, this holds if the cost-benefit ratio of exclusion, λ, is sufficiently low.

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